SOUTHWEST FISHERIES CENTER ADMINISTRATIVE

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COUNTRY STATEMENT - U.S.A.

1. FISHERIES ADMINISTRATION

The National Marine Fisheries Service (NMFS) was reorganized in 1978 to accommodate and facilitate the expanding and changing national goals and directions of the U.S.A. in the area of fisheries and related matters. To ensure that marine mammals and endangered species and problems relating to the marine habitat receive sufficient attention, two separate offices, the Office of Marine Mammals and Endangered species and the Office of Habitat Protection were established within the NMFS headquarters hierarchy. The other offices administering NMFS programs are the Office of Utilization and Development, Office of Resource Conservation and Management, Office of International Fisheries Affairs, and Office of Science and Environment.

2. PLANNING

On the national level, NMFS activities related to resource statistics programs include the collection of data on fish landings, effort, processing, employment, foreign trade, as well as social and economic data. Because much of this information is obtained by public surveys, survey designs are needed to collect these data. In 1978 major efforts were focused on the development of a 5-year plan for the collection of social and economic data needed for fishery management.

3. MARINE RESOURCES

NMFS conducts a multidisciplinary biological and socioeconomic research program for the protection and rational use of living marine resources and also for the maintenance and enhancement of the aesthetic, economic, and recreational values of these resources. An important component of this research is the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program.

3.1 Resource surveying, experimental and exploratory fishing, location of new fishing grounds

One of the four parts of the MARMAP program is Resource Surveys (others are Fishery Engineering, Fishery Oceanography, and Fishery Analysis), which uses NOAA ships plus chartered vessels to sample the abundance of eggs, larval, juvenile and adult stages fish and shellfish by area and by season. For example, relative to resource surveys, cruises were made by the research vessels Albatross IV and Delaware II off the northeastern U.S. dealing with sea scallops, ocean quahogs, and surf clams.

Off the southeastern coast, resource assessment surveys were made in U.S. continental shelf waters from Cape Hatteras to Florida under contract with the State of South Carolina and the RV Oregon II made surveys of Navassa Island, Navidad-Silver Bank, Puerto Rico, and the Virgin Islands.

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In the Bering Sea, surveys of king crab, Tanner crab, and groundfish were made by NOAA vessels and chartered trawlers.

At the Southwest Fisheries Center, an acoustic resonance frequency sonar technique was developed to determine the size of individual pelagic fish in schools which provides a method to determine recruitment into a fishery by rapidly counting the prerecruits. And following the formal signing of the Tripartite Cooperative Agreement for the Survey and Assessment of the Northwestern Hawaiian Islands in 1978 by the Fish and Wildlife Service, NMFS, and the State of Hawaii, a projected 5-year cooperative program to assess the living resources of the Northwestern Hawaiian Islands was initiated.

3.2 Fisheries biology (including methodology and techniques) studies on age determination, tagging, population dynamics

Biologists at the Southwest Fisheries Center developed a technique of great significance when they showed that fish can be aged by counting the daily growth rings on their otoliths. Following publication of the details of this technique, the methodology has been adopted by other NMFS biologists and by biologists throughout the world.

In a major mark-and-recapture experiment, the Southeast Fisheries Center released over 9,000 tagged shrimp in an area from Brownsville, Texas to Tampico, Mexico. More than 6,000 of the tagged shrimp have been recaptured and the data are being analyzed to obtain reliable estimates of growth and mortality and a delineation of subpopulations in the brown shrimp resource.

3.3 Fisheries oceanographic studies

Procedures were developed at the Southwest Fisheries Center to use surface maritime data to define the effects of the atmosphere on the ocean environment on smaller space scales than heretofore possible. The procedures have enabled the delineation of critical environmental processes on scales approaching that which may actually affect fish stocks. As an example, a striking relation has been found between spawning habits of commercially important fishes in the California Current and patterns of ocean surface drift. Spawning activities tended to occur at times and locations of minimal offshore transport.

3.4 Management, laws and regulations, control of pollution

United States fisheries in the fishery conservation zone (FCZ) continued to be managed under the Fishery Conservation and Management Act of 1976. Improved organizational and operational experience by the Regional Fishery Management Councils allowed progress on a considerable number of fishery management plans (FMP) and at the end of 1978, seven FMPs were in effect.

4. ACQUACULTURE (FRESHWATER AND OTHER)

4.1 Feeding, feedstuff

The food of larval mollusks are various species of microalgae. Experiments conducted at the Northeast Fisheries Center included the use of a new technique, using epifluorescence microscopy, to determine which microalgal species are ingested and digested by larval American oysters. Also, studies were carried out to determine the acute and chronic tolerances of several microalgal species to heavy metals such as zinc and cadmium.

At the Southeast Fisheries Center improvements were made in techniques to culture rotifers, which are the primary food of larval fishes like redfish, Sciaenops ocellata, and black drum, Pogonias chromis. Research also continued on the nutritional requirements of the Malaysian prawn, Macrobrachium rosenbergii. Studies indicated that neither animal nor plant sterol additions to the diet produced any better growth rate than a diet containing 32 percent menhaden fish meal. Preliminary studies on the effect of dietary fiber on Malaysian prawn revealed a beneficial effect on their growth brought about by an increase in the fiber level in their diet.

5. INFRASTRUCTURE

The policy engendered by NMFS is to foster the development of all sectors of the U.S. fishing industry--fishermen in the FCZ, in the Great Lakes, U.S. flag distant water fleets, and U.S. processors and distributors--through a program involving:

1) Increasing foreign markets access through negotiations and better information on market conditions and trade opportunities.

2) Facilitating industry access to private venture capital for vessels, processing plants, and support facilities.

3) Satisfying the need of the major fishing industry in some regions for publicly financed infrastructure such as ports and harbors.

4) Adapting existing technology and disseminating technological information to allow modernization and improvement of industry capital facilities.

6. UTILIZATION

6.1 Improvements in fresh fish handling and distribution, ice supply

Interim recommendations for handling and processing hake were provided to fishermen and processors in the developing Pacific coast hake fishery. Studies on the causes of mushiness in fresh and cooked hake documented the role of protozoans and postmortem enzyme levels in the flesh and also, the potential means of inhibiting the enzyme in raw and processed fish.

6.2 Product development, new processing methods and equipment

A commercial processor prepared excellent minced blocks by successfully using a modified heading and cleaning machine to remove blood and belly lining from silver hake. Also, by comparison with organaleptic evaluation and chemical and microbiological tests, an English instrument to measure fish deterioration was evaluated for precision and reliability on Atlantic cod, haddock, silver hake, and sand lance.

7. COOPERATIVES AND ENTERPRISES

7.1 Cooperatives

NMFS has a program to provide fishermen and other interested parties with information on organizing and operating fishery cooperatives. In response to complaints, fishery cooperatives are investigated to determine if they are in compliance with the provisions of the Fishery Cooperative Marketing Act of 1934, and are not monopolizing or restraining trade in interstate or foreign commerce such that it unduly increases the price of any aquatic product by the co-operatives.

8. FINANCING THE INDUSTRY

The government provides aid to the industry in various ways. Financial services are provided to the fishing industry under five programs. These are the Fishing Vessel Obligation Guarantee, the Fishing Vessel Capital Construction Fund, the Fishermen's Guaranty Fund, the Fishing Vessel and Gear Damage Compensation Fund, and the Fishermen's Contingency Fund.

ESTIMATING MONK SEAL POPULATIONS USING CHANGE-IN-RATIO AND LEAST SQUARES METHODS

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SUMMARY

This report describes some statistical methods for estimating the size of monk seal populations using observations of hauled out seals during the molting season. Two techniques are examined: (1) a change-in ratio (CIR) technique and (2) a least squares (LS) method. The first approach requires counts of the number of seals molting on each of a series of beach surveys and counts of pre-molt and post-molt seals on the first and last surveys of the series. The paper critically evaluates past efforts at applying the CIR method to monk seal populations and develops new estimators grounded in a stochastic model of molting dynamics.

The general theoretical model also gives rise to a set of LS estimators. They are based on a sequence of counts of molting seals. Both the CIR and LS methods rely on auxiliary information, namely haul out probabilities for different classes of seals and the probability distributions for time spent in the pre-molt state and in the molt state.

NOTATION

The following symbols and definitions will be adopted in describing the CIR and LS estimators and their variances. Throughout the paper, a hat (^) over a symbol signifies that the quantity is estimated. Some symbols of lesser importance are not listed here but are defined sufficiently in the text.

N = Total number of seals in the population, assumed constant during the molting season.

n = Number of beach surveys conducted. On each survey all hauled out seals are enumerated and classified as pre-molt, molting, or post-molt.

t_i = The instant in time at which the i^{th} survey is assumed to be conducted, measured from the beginning of the molting season, $i = 1, 2, \ldots, n$.

m_i = Number of molting seals counted on i^{th} survey, $i = 1, 2, \ldots, n$.

r_i = Number of pre-molt seals counted on the i^{th} survey, $i = 1, 2, \ldots, n$.

h_i = Total number of seals hauled out on the i^{th} survey, $i = 1, 2, \ldots, n$.

s_i = Number of molting seals in the population at time t_i.

p_i = Proportion of non-molting seals at time t_i which are in the pre-molt state, $i = 1, 2, \ldots, n$.

μ_i = Probability that a molting seal is hauled out at time t_i, $i = 1, 2, \ldots, n$.

b_i = Number of seals beginning molt in the time interval (t_{i-1}, t_i), $i = 2, 3, \ldots, n$.

c_i = Number of seals completing molt in the interval (t_{i-1}, t_i), $i = 2, 3, \ldots, n$.

ω_i = Number of seals which began molting on the i^{th} day of the molting season, in a sample of $\omega_\cdot$ seals.

π_i = Probability that a seal is molting at time t_i, $i = 1, 2, \ldots, n$.

ϕ_i = Probability that a seal begins molting in (t_{i-1}, t_i), $i = 2, 3, \ldots, n$.

L = Index of the last survey in a series of surveys contributing to a CIR estimate.

y = Amount of time a seal spends in the pre-molt state, measured from the beginning of the molting season (a random variable).

x = Amount of time a seal spends in the molting state (a random variable).

λ = Maximum value of y; i.e., maximum pre-molt time.

τ = Maximum value of x; i.e., maximum molt duration.

$\lambda + \tau$ = Length of molting season.

f(x) = Probability density function for x.

g(y) = Probability density function for y.

F(x) = Cumulative distribution function for x.

f_i = Probability that a seal completes its molt exactly i days after beginning it, $i = 1, 2, \ldots, \tau$.

g_i = Probability that a seal begins molting on the i^{th} day of the molting season (at the beginning of the day). $i = 1, 2, \ldots, \lambda$.

$\sigma^2(\cdot)$ = Variance of a random variable or statistic.

$V(\cdot)$ = Estimator of $\sigma^2(\cdot)$.

w_i = Statistical weight.

ε_i = Random error term (residual) for the i^{th} data point in LS model.

e = Base of natural logarithm

CHANGE-IN-RATIO ESTIMATES

Eberhardt's Model

Basic CIR methodology is discussed thoroughly in Seber (1973). The approach allows one to estimate the size of a population by knowing the proportion of the population in a specified class at the beginning and end of a time interval and the number of members added or removed from that class and the other classes during the interval.

The application of CIR estimators to monk seals was suggested by Eberhardt.[1] Assuming seals hauled out and observed during a survey were identifiable as pre-molt, molting or post-molt, he developed an estimator based on the proportions of non-molting seals in the post-molt class during two beach surveys and the number of seals observed in the molting class on all visits made in the intervening period. His approach assumes that visits are timed in such a way that all seals molting during the interval are observed and that none are counted more than once, or alternatively, that during the interval the multiple counts are exactly balanced by the number of molting seals not seen. He further assumes that all molting seals are hauled out at the time of surveys and that all non-molting seals haul out with equal probability when the first and last surveys are conducted. Under these conditions his estimator is

$$\hat{N}_E = \frac{\sum_{i=2}^{L} m_i + p_L(m_1 - m_L)}{p_1 - p_L} + m_1$$

where the symbols are defined in the previous section.

DeMaster's Model

Because such assumptions are likely to be violated in practice, DeMaster[2] suggested a procedure to adjust the counts of molting seals by dividing each count value by the expected number of times a molting seal will be seen during the surveys and by μ, the average haul out probability for molting seals. DeMaster calls the first of these constant divisors the "bias." In essence, his adjusted CIR estimator is

$$\hat{N}_D = \frac{\sum_{i=2}^{L}\left(\frac{m_i}{\text{bias} \cdot \mu}\right) + p_L\left(\frac{m_1 - m_L}{\mu}\right)}{p_1 - p_L} + \left(\frac{m_1}{\mu}\right) .$$

DeMaster computed the bias under the following restrictive set of assumptions:

(1) molt duration, x, ranges from 1 to 2I days, where I is a fixed interval between successive surveys,

(2) x is "normally distributed,"

(3) pre-molt time, y, is uniformly distributed [DeMaster made this assumption tacitly, but claims the results are not dependent on the distribution of y].

Under these conditions it is easy to show that his results reduce to bias = E(x)/I where E(•) is the expectation operator. This result requires that y is uniform and, in his case, that surveys are conducted at a constant interval, I. The distribution and range of x do not matter. DeMaster seems unaware of these conditions, and neglects other difficulties as well. For example, the bias factor is correct only for counts made at times t_i such that $\tau \leq t_i < \lambda$, where λ is the maximum time in the pre-molt state

and τ is the maximum molt duration (in DeMaster's case $\tau = 2I$). Hence, if the first (benchmark) survey is made at time t_1, and the k^{th} survey is the first survey such that $t_k > \tau$, then $m_2, m_3, \ldots, m_{k-1}$ should be excluded from the summation and the bias factor for m_k would be $E(x)/(t_k - t_1)$. Counts on subsequent surveys would be corrected by the usual bias factor, $E(x)/I$, subject to $t_i < \lambda$. For $\lambda \leq t_i < \lambda + \tau$ the bias term does not reduce to such simple expressions.

DeMaster suggested that an optimal survey design would result from choosing $I = E(x)$, but it is not clear why this would be so since, except for the difficulties mentioned here, it is a simple matter to compute and apply the bias factor. In any event, DeMaster's assumptions on the distribution of x actually result in bias = 1 regardless of I, so his particular model is inapplicable except in the moot case when $I = E(x)$.

A General Model

In most situations DeMaster's simple approach will not be satisfactory because y will not be uniformly distributed and it may not be possible or convenient to survey at regular intervals. What is needed is a more general procedure that will permit greater realism and more flexibility in survey design and analysis.

A general model can be constructed to accommodate any assumed distributions for x and y and any pattern of sampling. Let f(x) be the probability density function for x and g(y) be the density function for y. The molting season begins at time zero with all N seals in a pre-molt state and progresses until all seals have completed molting and entered the

post-molt state. Assuming x and y are independent, the probability that a seal is molting at time t_i is

$$\pi_i = \int_0^{t_i} g(u) \left(1 - F(t_i - u)\right) du$$

where $F(t_i - u) = \int_0^{t_i - u} f(x)dx$.

The expected number of seals observed molting at the time of the i^{th} survey is just

$$E(m_i) = \mu_i \pi_i N \qquad (1)$$

where μ_i is the probability a molting seal is hauled out at t_i. Further, the expected number of seals beginning the molt between the previous survey at t_{i-1} and the present visit is

$$E(b_i) = N \int_{t_{i-1}}^{t_i} g(u)du = N\phi_i$$

and the expected number of seals completing the molt in (t_{i-1}, t_i) is

$$E(c_i) = \frac{E(m_{i-1})}{\mu_{i-1}} - \frac{E(m_i)}{\mu_i} + E(b_i) \qquad i = 2, 3, 4, \ldots, n$$

Given the sequence of counts of molting seals, $m_1, m_2, m_3, \ldots$, and the auxiliary information on $g(\cdot)$, $f(\cdot)$, and $\mu(\cdot)$, the number of seals beginning the molt and the number completing the molt in any survey interval can easily be estimated:

$$\hat{b}_i = m_i\left(\frac{E(b_i)}{E(m_i)}\right) \qquad E(m_i) > 0 \tag{2}$$

and

$$\hat{c}_i = \frac{m_{i-1}}{\hat{\mu}_{i-1}} - \frac{m_i}{\hat{\mu}_i} + \hat{b}_i \,. \tag{3}$$

A pair of CIR estimators can now be derived:

$$\hat{N} = \frac{\sum_{i=2}^{L} \hat{b}_i + \hat{p}_L\left(\frac{m_1}{\hat{\mu}_1} - \frac{m_L}{\hat{\mu}_L}\right)}{\hat{p}_1 - \hat{p}_L} + \frac{m_1}{\hat{\mu}_1} \tag{4}$$

and

$$\hat{N}' = \frac{\sum_{i=2}^{L} \hat{c}_i - (1 - \hat{p}_L)\left(\frac{m_1}{\hat{\mu}_1} - \frac{m_L}{\hat{\mu}_L}\right)}{\hat{p}_1 - \hat{p}_L} + \frac{m_1}{\hat{\mu}_1}$$

where p_i is the proportion of non-molting seals at time t_i which are pre-molts. Note that $\hat{N} = \hat{N}'$. In the special case where y is uniformly distributed,

$$\pi_i \sim E(x) \qquad \text{for} \qquad \tau \leq t_i < \lambda$$

and

$$\hat{b}_i = \frac{m_i}{\mu_i}\left((t_i - t_{i-1})/E(x)\right) .$$

This removes the equal interval restriction of the DeMaster model, but not its other shortcomings.

Another special case of the CIR arises when the n surveys span the entire molting season, i.e., the first survey is at time zero and the n^{th} (L^{th}) survey is at time $t_n \geq \lambda + \tau$. In this event

$$\sum_{i=2}^{n} E(b_i) = \sum_{i=2}^{n} E(c_i) = N \,.$$

Further, $p_1 = 1$, $p_L = 0$ and the CIR estimator at (4) reduces to

$$\hat{N} = \sum_{i=2}^{L} \hat{b}_i$$

This is akin to the Johnson's "molt estimate," where the population size is estimated by summing the unadjusted m_i over the entire season. (This simple procedure has apparently worked satisfactorily with the proper choice of sampling interval, so that unobserved molting seals and multiple counts of molting seals balance out over the season.)

For ease in computing the estimates of b_i, it is convenient to approximate the continuous functions of $E(b_i)$ and $E(m_i)$ by discrete probability functions and replace the integrals by summations. Thus

$$\hat{b}_i = \frac{m_i \sum_{j=t_{i-1}}^{t_i} g_j}{\mu_i \left\{ \sum_{j=1}^{t_i} g_j - \sum_{j=1}^{t_i} g_j \sum_{k=1}^{t_i - j + 1} f_k \right\}}$$

where g_j = probability that a seal begins its molt on the j^{th} day of the molting season (at the beginning of the day), $j = 1, 2, \ldots, \lambda$.

f_k = probability that a seal completes its molt exactly k days after beginning it, $k = 1, 2, \ldots, \tau$.

Variance Estimates and Confidence Intervals

We turn now to the precision of the CIR estimates, as measured by $\sigma^2_{\hat{N}}$, the variance of $\hat{N}$. The estimator $\hat{N}$ at (4) is a function of several random variables, each with its own variance. The delta method and other results may be used to combine these in an approximation of $\sigma^2_{\hat{N}}$. Ignoring all covariances, and replacing expected values by observations or estimates, an approximation to $\sigma^2_{\hat{N}}$ is

$$V(\hat{N}) = A_1 \sum_{i=2}^{L} V(\hat{b}_i) + A_2 V(m_1) + A_3 V(m_L) + A_4 V(\hat{\mu}_1) + A_5 V(\hat{\mu}_L) + A_6 V(\hat{p}_L) + A_7 V(\hat{p}_1)$$

where $A_1 = \left(\hat{p}_1 - \hat{p}_L\right)^{-2}$

$$A_2 = \left(\frac{\hat{p}_L^2 + V(\hat{p}_L)}{\left(\hat{p}_1 - \hat{p}_L\right)^2} + 1\right)\left(\frac{1}{\hat{\mu}_1^2}\right)$$

$$A_3 = \frac{\hat{p}_L^2 + V(\hat{p}_L)}{\left(\hat{p}_1 - \hat{p}_L\right)^2 \hat{\mu}_L^2}$$

$$A_4 = \left(\frac{\hat{p}_L^2 + V(\hat{p}_L)}{\left(\hat{p}_1 - \hat{p}_L\right)^2} + 1\right)\left(\frac{m_1^2}{\hat{\mu}_1^4}\right)$$

$$A_5 = \frac{\hat{p}_L^2 + V(\hat{p}_L)\, m_L^2}{\left(\hat{p}_1 - \hat{p}_L\right)\hat{\mu}_L^4}$$

$$A_6 = \left(\frac{1}{\hat{p}_1 - \hat{p}_L}\right)^2\left\{\left(\frac{m_1}{\hat{\mu}_1} - \frac{m_L}{\hat{\mu}_L}\right) + \left(\hat{N} - \frac{m_1}{\hat{\mu}_1}\right)\right\}^2$$

$$A_7 = \left(\hat{N} - \frac{m_1}{\hat{\mu}_1}\right)^2\left(\frac{1}{\hat{p}_1 - \hat{p}_L}\right)^2$$

Here we use $V(\cdot)$ to denote an estimate of a sampling variance, $\sigma^2(\cdot)$. Of the component variance terms, $V(\hat{b}_i)$ requires further elaboration. Using the same approximating techniques as above, $V(\hat{b}_i)$ may be expressed as a function of $V(\hat{g}_i)$, $V(\hat{f}_i)$, $V(m_i)$, and $V(\hat{\mu}_i)$ as follows:

$$V(\hat{b}_i) = (\hat{\mu}_i\hat{\pi}_i)^{-2}\{m_i^2 V(\hat{\phi}_i) + \hat{\phi}_i^2 V(m_i) + V(m_i)V(\hat{\phi}_i)\}$$

$$+\left(\frac{m_i\hat{\phi}_i}{\left(\hat{\mu}_i\hat{\pi}_i\right)^2}\right)^2\{\hat{\mu}_i^2 V(\hat{\pi}_i) + \hat{\pi}_i^2 V(\hat{\mu}_i) + V(\hat{\pi}_i)V(\hat{\mu}_i)\}$$

where $$V(\hat{\phi}_i) = \sum_{j=t_{i-1}}^{t_i} V(\hat{g}_j)$$

and

$$V(\hat{\pi}_i) = \sum_{j=1}^{t_i} V(\hat{g}_j) + \sum_{j=1}^{t_i} \left\{ \hat{g}_j^2 \sum_{k=1}^{t_i-j+1} V(\hat{f}_k) + \left(\sum_{k=1}^{t_i-j+1} \hat{f}_k \right)^2 V(\hat{g}_j) + V(\hat{g}_j) \sum_{k=1}^{t_i-j+1} V(\hat{f}_k) \right\}.$$

To complete the estimation of $V(\hat{N})$, some assumptions have to be made about the distributions of the component random variables. A reasonable set of assumptions may be the following:

(1) $V(m_i)$: The m_i could be considered Poisson, hence $V(m_i) = m_i$. Or, given the total count of seals on the i^{th} visit, h_i, m_i could be taken as binomial random variable in which case $V(m_i) = m_i\left(1 - \frac{m_i}{h_i}\right)$

(2) $V(\hat{p}_i)$: Both $\hat{p}_1$ and $\hat{p}_L$ are binomial given the total counts of non-molting seals on the first and L^{th} surveys. Thus

$$V(\hat{p}_i) = \frac{r_i}{\left(h_i - m_i\right)^2}\left(1 - \frac{r_i}{h_i - m_i}\right)$$

where r_i = number of pre-molt seals counted on i^{th} survey.

Here we assume pre-molt and post-molt haul out probabilities are the same on the first survey, and also on the L^{th} survey.

(3) $V(\hat{\mu}_i)$: Presumably the haul out probabilities for molting seals are estimated from sampling binomial distributions also. Thus

$$V(\hat{\mu}_i) = \left(\frac{m_i}{s_i^2}\right)\left(1 - \frac{m_i}{s_i}\right)$$

where s_i = total population of molting seals at time t_i

(4) $V(\hat{g}_i)$ and $V(\hat{f}_i)$: Elements of the probability distributions for pre-molt time and duration of molt are presumably estimated by sampling multinomial populations. Thus the i^{th} element of the pre-molt time distribution is estimated as

$$\hat{g}_i = \frac{\omega_i}{\sum_{i=1}^{\lambda} \omega_i} = \frac{\omega_i}{\omega_\cdot}$$

with estimated variance $V(\hat{g}_i) = \left(\frac{\omega_i}{\omega_\cdot^2}\right)\left(1 - \frac{\omega_i}{\omega_\cdot}\right)$, $\quad i = 1, 2, \ldots, \lambda$

where ω_i = number of seals beginning their molt on the i^{th} day of the season. Similar equations would apply to $\hat{f}_i$ and $V(\hat{f}_i)$, $i = 1, 2, \ldots, \tau$.

Approximate 95% confidence limits on N may be computed in the usual manner, assuming normality of $\hat{N}$, as

$$\hat{N} \pm 2V(\hat{N})^{1/2} .$$

LEAST SQUARES ESTIMATES

The general model of molting dynamics leads to other estimators besides the CIR. In particular, Equation (1) immediately suggests a set of moment estimators for N, namely

$$\hat{N}_i = \frac{m_i}{\hat{\mu}_i \hat{\pi}_i} \qquad i = 1, 2, \ldots, n$$

However, since each survey produces a separate estimate the question now is how best to combine the n estimates. An intuitively obvious procedure would be to simply take the arithmetic mean of the $\hat{N}_i$, i.e.,

$$\hat{N} = \sum_{i=1}^{n} \hat{N}_i / n \ .$$

Another approach leading to the same result is to consider a simple least squares criterion, i.e., choose $\hat{N}$ as the value of N which minimizes

$$S = \sum_{i=1}^{n} w_i \left(m_i - E(m_i) \right)^2 \qquad (5)$$

where w_i is a statistical weight to be specified. This model assumes additive error, i.e., $m_i = \mu_i \pi_i N + \varepsilon_i$ where the ε_i are independent random errors with zero mean and covariance matrix $W^{-1}\sigma_\varepsilon^2$ and W is a diagonal matrix of the weights. The general solution to (5) is

$$\hat{N} = \frac{\sum_{i=1}^{n} w_i \pi_i \mu_i m_i}{\sum_{i=1}^{n} w_i (\mu_i \pi_i)^2} \ .$$

Some special cases of interest may be obtained directly using the results in Draper and Smith (1966, p. 80-81) or other standard statistical texts. Among these is the case where w_i is assumed proportional to $(\mu_i \pi_i)^{-2}$, and this is

$$\hat{N} = \frac{\sum_{i=1}^{n} \frac{m_i}{\mu_i \pi_i}}{n} = \frac{\sum_{i=1}^{n} \hat{N}_i}{n}$$

as in the intuitive estimate above.

The variance of $\hat{N}$ may be estimated by

$$V(\hat{N}) = \frac{\sum_{i=1}^{n} (\hat{N}_i - \hat{N})^2}{n(n-1)} .$$

Another set of least squares estimators is appropriate when the error is multiplicative, i.e., when the model is $m_i = \mu_i \pi_i N e^{\varepsilon_i'}$. In this event

$$\ln m_i = \ln N + \ln(\mu_i \pi_i) + \varepsilon_i'$$

where ε_i' is independently distributed with mean zero and covariance matrix $W'^{-1}\sigma^2_{\varepsilon'}$. Now the least squares estimate of $\ln N$ is found by minimizing

$$S' = \sum_{i=1}^{n} w_i' (\ln m_i - (\ln N + \ln(\mu_i \pi_i)))^2 .$$

The general result is

$$\widehat{\ln(N)} = \frac{\sum_{i=1}^{n} w_i' \ln\left(\frac{m_i}{\mu_i \pi_i}\right)}{\sum_{i=1}^{n} w_i'} .$$

When the variance of m_i is proportional to $(\mu_i \pi_i)^2$ as in the special case discussed above, it is well-known that a logarithmic transformation will stabilize the variance so equal weighting will be appropriate in the logarithmic model. Hence in this special case,

$$\widehat{\ln N} = \frac{\sum_{i=1}^{n} \ln\left(\frac{m_i}{\mu_i \pi_i}\right)}{n} = \frac{\sum_{i=1}^{n} \ln \hat{N}_i}{n}$$

with estimated variance

$$V(\widehat{\ln N}) = \frac{\sum_{i=1}^{n} \left(\ln \hat{N}_i - \widehat{\ln N}\right)^2}{n(n-1)} .$$

The corresponding estimate of N is

$$N^* = e^{\widehat{\ln N}} = \left\{ \prod_{i=1}^{n} \hat{N}_i \right\}^{1/n}$$

i.e., the geometric mean of the individual $\hat{N}_i$.

When the additive model is employed, confidence limits on N may be estimated assuming normality of $\hat{N}$. Approximate 95% confidence limits then are $\hat{N} \pm 2V(\hat{N})^{1/2}$. When the multiplicative model is used, confidence limits for N may be constructed by transforming limits for $\ln N$. Thus if $\widehat{\ln N}$ is normally distributed, approximate 95% confidence limits on N are $N^* e^{\pm 2V(\widehat{\ln N})^{1/2}}$.

NUMERICAL EXAMPLES

To demonstrate the use of the estimation techniques, consider the following hypothetical set of survey observations:

i	t_i	h_i	r_i	m_i
1	0	56	56	0
2	8	49	48	1
3	16	47	46	1
4	24	58	57	0
5	32	61	57	3
6	40	47	43	2
7	48	51	40	7
8	56	61	45	5
9	64	70	49	11
10	72	74	41	16
11	80	77	30	18
12	88	75	28	9
13	96	81	25	11
14	104	62	16	7
15	112	69	15	12
16	120	67	7	9

In addition to this set of survey observations it is assumed from other studies that the probability functions for pre-molt time and molt duration are as follows:

$$g_i = \begin{cases} 0.0005 & i = 1, 2, \ldots, 15 \\ 0.001 & i = 16, 17, \ldots, 30 \\ 0.0034 & i = 31, 32, \ldots, 45 \\ 0.0078 & i = 46, 47, \ldots, 60 \\ 0.0137 & i = 61, 62, \ldots, 75 \\ 0.0127 & i = 76, 77, \ldots, 90 \\ 0.0074 & i = 91, 92, \ldots, 105 \\ 0.0083 & i = 106, 107, \ldots, 120 \\ 0 & i = 121, 122, \ldots \end{cases}$$

$$f_i = \begin{cases} 0 & i = 1, 2, 3 \\ 0.0139 & i = 4 \\ 0.0208 & i = 5 \\ 0.903 & i = 6 \\ 0.0972 & i = 7 \\ 0.2222 & i = 8 \\ 0.1875 & i = 9 \\ 0.1806 & i = 10 \\ 0.0972 & i = 11 \\ 0.0764 & i = 12 \\ 0.139 & i = 13 \\ 0 & i = 14, 15, \ldots \end{cases}$$

It is further assumed that at times t_1 and t_{11} the pre-molt and post-molt seals are hauled out with equal probability. This gives

$$\hat{p}_1 = \frac{56}{56 - 0} = 1.0$$

and

$$\hat{p}_L = \hat{p}_{11} = \frac{30}{77 - 18} = 0.5085 .$$

In addition, it is known that $\mu_i = 0.91$ for all i. Under these conditions the following basic statistics are computed:

i	$\hat{\pi}_i$	$\hat{\phi}_i$	$\hat{N}_i$	$\hat{b}_i$	$\hat{c}_i$
2	0.00358	0.0040	307	1.2	0.1
3	0.00441	0.0045	249	1.1	1.1
4	0.00767	0.0080	--	5.4	3.2
5	0.01262	0.0128	261		
6	0.02634	0.0272	83	2.3	3.4
7	0.03979	0.0404	193	7.8	2.3
8	0.06093	0.0624	90	5.6	7.8
9	0.08451	0.0860	143	12.3	5.7
10	0.10713	0.1096	164	18.0	12.5
11	0.10218	0.1046	194	20.2	18.0
12	0.09931	0.1016	100	10.1	20.0
13	0.06843	0.0698	177	12.3	10.1
14	0.05787	0.0592	133	7.9	12.3
15	0.06381	0.0655	207	13.5	8.0
16	0.06490	0.0664	152	10.1	13.4

Change-in-Ratio Estimates

To compute the CIR estimates we use statistics for i = 2, 3, ..., 11. On the fourth survey $m_i = 0$, so we derive a combined estimate of the quantity $(b_4 + b_5)$ which is (3) (0.0080 +0.0128)/(0.01262) (0.91) = 5.4. Also we estimate $(c_4 + c_5)$ by (1/0.91) - (3/0.91) + 5.4 = 3.2.

The CIR estimate of N based on the b_i is

$$\hat{N} = \frac{73.9 - (0.5085)\left(\frac{18}{0.91}\right)}{1.0 - 0.5085} + 0$$

$$= \frac{73.9 - 10.0582}{0.4915}$$

$$= 129.9 .$$

The corresponding estimate based on the c_i is

$$\hat{N}' = \frac{54.1 + (0.4915)\left(\frac{18}{0.91}\right)}{0.4915} + 0$$

$$= \frac{54.1 + 9.722}{0.4915}$$

$$= 129.8$$

which shows that $\hat{N}$ and $\hat{N}'$ are identical.

[An updated version of this paper will include variance estimates and confidence limits based on the CIR methodology.]

Least Square Estimates

Based on the 14 individual estimates of N, the additive error model yields

$$\hat{N} = \frac{\sum_{i=1}^{14} \hat{N}_i}{14} = 175.2$$

with variance estimate

$$V(\hat{N}) = 311.87 .$$

So 95% confidence limits on N are 139.9 and 210.5.

The multiplicative model gives an estimate of

$$N^* = \left(\prod_{i=1}^{14} \hat{N}_i \right)^{1/14} = 163.4$$

with 95% confidence limits on N of 132.3 and 201.9.

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TEXT FOOTNOTES

1. Personal communication between Lee Eberhardt and Brian and Pattie Johnson, 3 September 1979.

2. Personal communication from Douglas DeMaster to Robert Hofman, Marine Mammal Commission.

80-3

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AN ITERATIVE AGGREGATION PROCEDURE FOR MARKOV DECISION PROCESSES

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ABSTRACT

An iterative aggregation procedure is described for solving large scale, finite state, finite action Markov decision processes (MDP). At each iteration, an aggregate master problem and a sequence of smaller subproblems are solved. The weights used to form the aggregate master problem are based on the estimates from the previous iteration. The subproblems are each a finite state, finite action MDP with a reduced state space and unequal row sums. Global convergence is proven for the iterative aggregation process under very weak assumptions. The proof of convergence relates this iterative aggregation technique to other iterative techniques that have been suggested for solving nonaggregate linear programs.

1. INTRODUCTION

Most real life applications of Markov decision processes (MDP's) require the ability to solve very large problems; this is particularly true if the state can be represented as a vector of dimensions greater than two or three. The major limitation to solving large scale MDP's appears to be in-core storage, as computers are now capable of performing iterations of algorithms for MDP's quickly. However, a 7-dimension state with only five grid points per dimension would have 78,125 states and a transition matrix for each policy that could not be stored in present day computers. In this paper, an iterative aggregation procedure is described for solving large scale MDP's.

The procedure to be described uses the linear programming (LP) formulation of a discounted MDP [4] and employs ideas for aggregation of LP's developed in [1, 5, 12, 13, 14, 17, 18, 19]. In particular, for the special case of MDP's, the procedure is an extension of Zipkin's fixed-weight row and column aggregation of LP's [18, 19] with optimal disaggregation, and of the extensive Russian literature on iterative aggregation procedures for LP's [1, 5, 12, 13, 14]. At each iteration, the restrictions on how an aggregate problem may be formed are similar to those described in Whitt [15] and Thomas [11] for approximating MDP's.

The major result of this paper is that if at each iteration the weights for aggregating the rows and columns of the LP are chosen properly, then the iterative procedure of aggregation and optimal disaggregation converges globally to an optimal primal and dual solution of the MDP. Convergence is proven using Zangwill's Convergence Theorem A [16, p. 19] for algorithms.

For MDP's, the results extend those of Zipkin by showing how to iteratively choose the weights for fixed-weight row and column aggregation,

and by proving convergence of this procedure. Also, it is proven that for MDP's the LP described in [19] for optimal disaggregation can be reduced to solving a smaller MDP with unequal row sums (i.e., state and action dependent discount factors). This allows the subproblems to be solved by more efficient iterative techniques, rather than by linear programming.

The Russian literature on iterative aggregation procedures for LP's involves solving sequences of complicated unconstrained quadratic programming problems. Proofs of convergence (particularly global convergence) when they have been found [5, 14], are complicated. The iterative aggregation procedure presented in this paper was motivated by the realization that the quadratic programming problems in the Russian literature on aggregation are precisely exterior penalty functions for LP's. When the quadratic programs are written as LP's, many of the constraints are redundant. This yields a simpler iterative procedure and a stronger proof of convergence.

The major drawback of the iterative aggregation procedure is that calculating the new row weights for each iteration is equivalent to a dual variable update when using multiplier methods [10], and requires the computational equivalent of one iteration of successive approximations on the full MDP. It is believed that the iterative aggregation process should converge more quickly for large problems then attempting successive approximations on the original MDP. However, several alternative procedures are suggesting for calculating the new row weights each iteration that require less computation, but for which convergence isn't proven.

2. THE MODEL

A Markov process is to be controlled over an infinite planning horizon. At the start of each period, a state i from a finite set of N states is observed, an action k is chosen from a finite set of K actions (where for convenience it is assumed the same K actions are available at each state), and a transistion is made to state j at the start of the next period with probability $p(i, j:k)$.

In each period, if state i is observed and action k is selected, a cost $c(i, k)$ is incurred. The cost in period t is discounted by a factor β^{t-1}, $0 \leq \beta < 1$, and it is desired to minimize the expected total cost over the infinite planning horizon. It is assumed that $c(i, k)$ is bounded, or equivalently that $0 \leq c(i, k) < \infty$ for all i and k. It is well known [4] that a solution to this MDP can be found by solving the following linear programming problem (LP):

$$\text{Maximize} \quad \sum_{i=1}^{N} v(i)$$

$$\text{s.t.} \quad \sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k)\right) v(j) \leq c(i, k) \qquad \begin{matrix} i = 1, \ldots, N \\ k = 1, \ldots, K \end{matrix} \qquad (2.1)$$

where $\delta_{ij} = \begin{cases} 0 & \text{if } i \neq j \\ 1 & \text{if } i = j \end{cases}$. Dual variables are denoted by $u(i, k)$, $i = 1, \ldots, N$; $k = 1, \ldots, K$, and let $v = \{v(i)\}$, $u = \{u(i, k)\}$. Optimal primal and dual variables are denoted by $\bar{v} = \{\bar{v}(i)\}$ and $\bar{u} = \{\bar{u}(i, k)\}$.

In forming an aggregate problem attention is restricted to a reasonable subset of possible aggregations, similar to those described in Whitt [15]. The idea is to form a reduced MDP with $N' \leq N$ aggregate states and $K' \leq K$ actions. In the LP formulation, each state has an associated column and each state-action pair has an associated row. The restriction is essentially that if two states have their associated columns aggregated together, then the rows associated with each state-action pair must also be aggregated across the states. Similarly, if two rows representing the same action from two states are aggregated together, then all the rows for these two states must be aggregated, as must the two columns associated with these states. Finally the row representing action k^1 from state i can only be aggregated with the row representing action k^2 from state j, if first the (i, k^1)-row and (j, k^1)-row are aggregated, then the (i, k^2)-row and (j, k^2)-row are aggregated, and then the two new aggregate rows are aggregated.

More formerly, the aggregate rows and columns can be formed as follows. Let σ be a partition of $\{1, 2, \ldots, N\}$ and let ρ be a partition of $\{1, 2, \ldots, K\}$. Let $\{S_n\}$, $n = 1, \ldots, N' \leq N$ be the set of indices contained in the n^{th} subset of σ. Similarly, let $\{A_\ell\}$, $\ell = 1, \ldots, K' \leq K$ be the set of indices contained in the ℓ^{th} subset of ρ. Hence S_n references the states that are aggregated into the n^{th} aggregate state, and A_ℓ references the actions that are aggregated into the ℓ^{th} aggregate action. For notational convenience it is assumed that the partitions do not change with each iteration. However, the proofs do not depend on this assumption, and some basis for choosing the partitions at each iteration are supplied by the algorithm.

Following [5, 14], assume at the t^{th} iteration estimates v^t, u^t for v, u are given. Define the following aggregated terms [18].

$$c^{t+1}(n, \ell) = \frac{\sum_{k\in A_\ell} \sum_{i\in S_n} c(i, k)\, u^t(i, k)}{\sum_{k\in A_\ell} \sum_{i\in S_n} u^t(i, k)} \qquad \begin{array}{l} n = 1, \ldots, N'; \\ \ell = 1, \ldots, K'. \end{array} \tag{2.2a}$$

$$\hat{p}^{t+1}(i, m:k) = \frac{\sum_{j\in S_m} \left(\delta_{ij} - \beta p(i, j:k)\right) v^t(j)}{\sum_{j\in S_m} v^t(j)} \qquad \begin{array}{l} i = 1, \ldots, N; \\ m = 1, \ldots, N'; \\ k = 1, \ldots, K. \end{array} \tag{2.2b}$$

$$p^{t+1}(n, m:\ell) = \frac{\sum_{k\in A_\ell} \sum_{i\in S_n} \hat{p}^{t+1}(i, m:k) u^t(i, k)}{\sum_{k\in A_\ell} \sum_{i\in S_n} u^t(i, k)} \qquad \begin{array}{l} n = 1, \ldots, N'; \\ m = 1, \ldots, N'; \\ \ell = 1, \ldots, K'. \end{array} \tag{2.2c}$$

Let $z(n)$, $n = 1, \ldots, N'$ be an optimal value function for the aggregate MDP. Then it is readily seen that the aggregate objective function is maximize $\sum_{n=1}^{N'} z(n)$.

Let $f_o(x)$, $f_i(x)$, $i = 1, \ldots, k$ be concave functions. For the problem:

$$\text{Max } f_o(x)$$

$$\text{s.t. } f_i(x) \leq 0 \qquad i = 1, \ldots, k$$

the Lagrangean $L(x, \lambda)$ is given by:

$$\begin{cases} f_o(x) + \sum_i \lambda_i f_i(x) & \text{if } \lambda_i \geq 0 \qquad i = 1, \ldots, k \\ \infty & \text{otherwise} \end{cases}$$

Let $L(\lambda) = \max_x L(x, \lambda)$ and $L(x) = \min_\lambda L(x, \lambda)$, and let x^+, λ^+ be the optimal values. The well known result that

$$L(x^+, \lambda) \leq L(x^+, \lambda^+) \leq L(x, \lambda^+)$$

is used in theorem 3.2.

3. THE ALGORITHM AND ITS PROPERTIES

The iterative aggregation procedure is as follows. Choose v^0, u^0 arbitrary, but so $\infty > v^0 \geq 0$ and $\infty > u^0 \geq 0$. Assume that after iteration t, v^t and u^t are given.

Step (i) Form the aggregate coefficients defined in (2.2).

Step (ii) Solve the master program:

$$\text{Maximize} \sum_{n=1}^{N'} z(n)$$

$$\text{s.t.} \sum_{m=1}^{N'} p^{t+1}(n, m:\ell)\, z(m) \leq c^{t+1}(n, \ell) \qquad \begin{matrix} n = 1, \ldots, N' \\ \ell = 1, \ldots, K' \end{matrix} \tag{3.1a}$$

Denote a primal solution to (3.1a) by $z^{t+1} = \{z^{t+1}(n)\}$, and the dual solution by $\lambda^{t+1} = \{\lambda^{t+1}(n, \ell)\}$.

Step (iii) Solve N' LP's

$$\text{Maximize} \sum_{i \in S_n} v(i) \tag{3.1b}$$

$$\text{s.t.} \sum_{j \in S_n} \left(\delta_{ij} - \beta p(i, j:k)\right) v(j) \leq z^{t+1}(n)\hat{p}^t(i, n:k) \qquad \begin{matrix} i \in S_n \\ k = 1, \ldots, K. \end{matrix}$$

Denote the optimal values to (3.1a) by $v^{t+1} = \{v^{t+1}(n)\}$ and the optimal dual variables by $\pi_n^{t+1}(i, k)$, where the subscript n denotes that $i \in S_n$.

Step (iv) Update the dual variables

$$u^{t+1}(i,k) = \left\{ \frac{u^t(i,k)\lambda^{t+1}(n,\ell)}{\sum_{k\in A_\ell} \sum_{i\in S_n} u^t(i,k)} - \left(c(i,k) + \beta \sum_{j=1}^{N} p(i,j:k)v^{t+1}(j) - v^{t+1}(i) \right) \right\}^+$$

$$i \in S_n;\ k \in A_\ell \qquad (3.2)$$

where $\{a\}^+ = \max(a, 0)$.

The Russian literature [12] also suggests updating the dual variables using the formula

$$u^{t+1}(i,k) = \frac{\lambda^{t+1}(n,\ell)}{\sum_{k\in A_\ell} \sum_{i\in S_n} u^t(i,k)} \left\{ u^t(i,k) - \left(c(i,k) + \beta \sum_{j=1}^{N} p(i,j:k)v^{t+1}(j) - v^{t+1}(i) \right) \right.$$

A fixed point of the iterative process, if one exists, is denoted by v^*, u^*. The corresponding values of z, λ are denoted by z^*, λ^*. Note that the N' LP's (3.1b) have dual LP's that are Leontief [6], and hence can be solved by iterative techniques. Each LP can also be viewed as an MDP with unequal row sums. The update (3.2) is a modification of the usual update in the method of multipliers.

It is conjectured that the dual LP to (3.1a) will also be Leontief. This has been true in the few small numerical examples solved to date using the algorithm.

An alternative to step (iii) that reduces the computation effort is to use the fixed-weight disaggregate value [17, 18, 19]:

$$v^{t+1}(i) = \frac{v^t(i) z^{t+1}(n)}{\sum_{j \in S_n} v^t(j)} \qquad i \in S_n \tag{3.3}$$

Similarly, step (iv) can be replaced by a fixed-weight disaggregate:

$$u^{t+1}(i, k) = \frac{u^t(i, k) \lambda^{t+1}(n, \ell)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^t(i, k)} \qquad i \in S_n;\ k \in A_\ell \tag{3.4}$$

or, by noting that the $\pi_n^{t+1}(i, k)$ in step (iii) are disjoint, let

$$u^{t+1}(i, k) = \pi_n^{t+1}(i, k). \tag{3.5}$$

Zipkin [19] shows that optimal disaggregation improved upon fixed-weight disaggregation. Zipkin defines optimal disaggregation as solving

$$\text{Maximize} \quad \sum_{i \in S_n} v(i)$$

$$\text{s.t.} \quad \sum_{j \in S_n} \left(\delta_{ij} - \beta p(i, j:k)\right) v(j) \leq z^{t+1}(n) \hat{p}^t(i, n:k) \qquad i \in S_n \tag{3.6a}$$
$$k = 1, \ldots, K$$

$$\sum_{j \in S_n} \left(-\beta p(i, j:k)\right) v(j) \leq z^{t+1}(n) \hat{p}^t(i, n:k) \qquad i \notin S_n \tag{3.6b}$$
$$k = 1, \ldots, K.$$

Denote as before the optimal dual variables to (3.6a) as $\pi_n^{t+1}(i, k)$, and those of (3.6b) by $w_p^{t+1}(i, k)$, $p \neq n$. Before proving properties of the iterative algorithm procedure, it is necessary to prove that a solution to (3.1b) solves (3.6).

Lemma 3.1 In the LP (3.6a), none of the constraints (3.6b) are binding, that is $w_p^{t+1}(i, k) \equiv 0$.

Proof. The dual LP to (3.6) has the following general form

$$\text{Minimize} \quad \sum_{i \in S_n} \sum_{k=1}^{K} \pi_n(i, k)h(i, k) + \sum_{i \notin S_n} \sum_{k=1}^{K} w_p(i, k)h(i, k)$$

$$\text{s.t.} \quad \sum_{j \in S_n} \sum_{k=1}^{K} \left(\delta_{ij} - \beta p(j, i:k)\right)\pi_n(i, k) = 1$$

$$\sum_{j \notin S_n} \sum_{k=1}^{K} \left(-\beta p(j, i:k)\right)w_p(i, k) = 1$$

$$i \in S_n$$

The dual LP is obviously Leontief. The lemma follows from theorem 2.5.1 in [6].

□

The existence of an optimal solution to (2.1) has been well-established. The existence of a fixed point (v^*, u^*) for the iterative process will be proven by showing that (v^*, u^*) is a fixed point if and only if it is optimal in (2.1).

Theorem 3.1 (v^*, u^*) is a fixed point of the iterative process described in steps (i)-(iv) if and only if it is primal and dual optimal for (2.1).

Proof. $(\bar{v}, \bar{u})$ is a fixed point.

The proof proceeds by showing that if $v^t = \bar{v}$, $u^t = \bar{u}$, then $z^{t+1}(n) = \sum_{i \in S_n} \bar{v}(i)$, and $\lambda^{t+1}(n, \ell) = \sum_{i \in S_n} \sum_{k \in A_\ell} \bar{u}(i, k)$. These values are optimal

in the master problem if they are feasible and if they satisfy complementarity conditions. The latter is

$$\sum_{n=1}^{N'}\sum_{\ell=1}^{K'}\left\{\left(\sum_{n=1}^{N}\left(\sum_{i\in S_n}\bar{v}(i)\right)\sum_{j\in S_n}\left(\delta_{ij}-\beta p(i,j:k)\right)\frac{\bar{v}(i)}{\sum_{i\in S_n}\bar{v}(i)}-c(i,k)\right)\left(\frac{\bar{u}(i,k)}{\sum_{i\in S_n}\sum_{k\in A_\ell}\bar{u}(i,k)}\right)\right\}$$

$$\left(\sum_{i\in S_n}\sum_{k\in A_\ell}\bar{u}(i,k)\right)=0\,.$$

After cancelling out terms, this reduces to:

$$\sum_{i=1}^{N}\sum_{k=1}^{K}\left(\bar{v}(i)-\left(c(i,k)+\beta\sum_{j=1}^{N}p(i,j:k)\right)\bar{v}(i)\right)\bar{u}(i,k)=0$$

the complementarity condition for (2.1), which is true by assumption. Since $\bar{v}$, $\bar{u}$ are primal and dual feasible, positive weighted sums of the rows and columns cannot change this. Hence $z^{t+1}(n)=\sum_{i\in S_n}\bar{v}(i)$ and $\lambda^{t+1}(n,\ell)=\sum_{i\in S_n}\sum_{k\in A_\ell}\bar{u}(i,k)$ are primal and dual feasible in the master problem.

Depending on how the partitions are chosen, $\lambda^{t+1}(n,\ell)=\sum_{i\in S_n}\sum_{k\in A_\ell}\bar{u}(i,k)$ may be positive for more than N' values of (n,ℓ). However, at $z^{t+1}(n)=\sum_{i\in S_n}\bar{v}(i)$, the $(n,\ell)^{th}$ constraint in (3.1a) becomes:

$$\frac{1}{\sum_{k\in A_\ell}\sum_{j\in S_n}\bar{u}(i,k)}\sum_{k\in A_\ell}\sum_{j\in S_n}\bar{u}(i,k)\left[\sum_{j=1}^{N}\left(\delta_{ij}-\beta p(i,j:k)\right)\bar{v}(j)-c(i,k)\right]\leq 0$$

which from the optimality of $(\bar{v}, \bar{u})$ is at equality for each (n, ℓ). The master LP hence has possibly degenerate optimal solutions. The values $\lambda^{t+1}(n, \ell) = \sum_{i \in S_n} \sum_{k \in A_\ell} \bar{u}(i, k)$ in practice can be found by finding all possible optimal solutions to (3.1a).

Using the LP form of step (iii) given in (3.6), it is evident that $v^{t+1} = \bar{v}$. Since $\bar{v}$ is feasible and optimal, the second term on the right-hand side of (3.2) is always nonpositive. The first term reduces to $\bar{u}(i, k)$. If $\bar{u}(i, k)$ is zero, then the brackets imply $\bar{u}^{t+1}(i, k) = 0 = \bar{u}(i, k)$. If $\bar{u}(i, k) > 0$, then

$$c(i, k) + \beta \sum_{j=1}^{N} p(i, j:k)\bar{v}(j) - \bar{v}(j) = 0, \text{ so again } u^{t+1}(i, k) = \bar{u}(i, k).$$

(v^*, u^*) is optimal in (2.1)

(v^*, u^*) is optimal in (2.1) if v^* is primal feasible, u^* is dual feasible and (v^*, u^*) satisfies the complementarity condition. As (v^*, u^*) is a fixed point by assumption, then $z^*(n) = \sum_{i \in S_n} v^*(i)$, $\lambda^*(n, \ell) = \sum_{i \in S_n} \sum_{k \in A_\ell} u^*(i, k)$. From (3.2), v^* is feasible in (2.1) or else u^* would not be a fixed point.

As above, writing out the complementarity conditions for the master problem (3.1a) at (z^*, λ^*) and substituting in their values yields:

$$\sum_{i=1}^{N} \sum_{k=1}^{K} \left(v^*(i) - \left(c(i, k) + \beta \sum_{j=1}^{N} p(i, j:k) v^*(j) \right) \right) u^*(i, k) = 0$$

so (v^*, u^*) satisfy the complementarity condition.

At $\lambda^*(n, \ell) = \sum_{i \in S_n} \sum_{k \in A_\ell} u^*(i, k)$, (3.2) becomes

$$u^*(i, k) = \left(u^*(i, k) - \left(c(i, k) + \beta \sum_{j=1}^{N} p(i, j:k) v^*(j) - v^*(i) \right) \right)^+$$

which is the usual dual update for the method of multipliers. As $u^*(i, k)$ is invariant at v^*, it follows from [10] that u^* is dual optimal.

□

Zipkin [19] in developing bounds for aggregate LPs, shows that optimal weightings should be proportional to optimal values. A theorem similar to theorem 3.1 is proven in [14]. The possible degeneracy of the master LP (3.1a) suggests that at each iteration, partitions should be chosen such that $\sum_{k \in A_\ell} \sum_{j \in S_n} u^t(i, k) > 0$ for only one ℓ for each $n = 1, \ldots, N'$. In this case, the algorithm reduces to an aggregation procedure for policy evaluation, and a multiplier type step for policy improvement. Otherwise, partitions should be chosen such that the dual constraint matrix is Leontief.

Theorem 3.2 states the main results of this paper, that under very weak conditions the iterative aggregation procedure converges to a solution of (2.1). Note that the iterative aggregation procedure can be viewed as a point to set map A: $R_+^N \times R_+^{N \times K} \to R_+^N \times R_+^{N \times K}$. The theorem is proven by showing that the algorithm satisfies the conditions of Zangwill's theorem A [16].

Theorem 3.2 Assume for $(v^0, u^0) \geq 0$ that v', u' are nonnegative and bounded when one iteration of the procedure is performed. Let $\{(v^t, u^t)\}_{t=1}^{\infty}$ be the sequence of vectors generated by the algorithm. Then either $\{(v^t, u^t)\}$ converges to $(\bar{v}, \bar{u})$ or else there is a convergent subsequence with $(\bar{v}, \bar{u})$ as the limit of the subsequence.

Proof. It is necessary to show that A is an upper semicontinuous point to set map defined on a compact set, and that there exists some function that changes monotonically with each iteration of the algorithm.

(i) If the algorithm converges, it converges to a fixed point.

Denote the assumed limit by (v', u'). Since the sequence $\{(v^t, u^t)\}$ converges on a metric space, there exists a metric d and a t^* such that $d\left((v^t, u^t), (v', u')\right) < \varepsilon$, for every $\varepsilon > 0$. Also, for every $\varepsilon > 0$ there exists a $\bar{t}$ such that for $t' \geq \bar{t}$, $t'' \geq \bar{t}$, $d\left((v^{t'}, u^{t'}), (v^{t''}, u^{t''})\right) < \varepsilon$. Combining inequalities says that $d\left((v^t, u^t), (v^{t+1}, u^{t+1})\right) \to 0$ as t approaches infinity, hence (v', u') must be a fixed point.

(ii). The point to set map A is upper semicontinuous (closed).

Since the partitions being used are the same each iteration, there exists three constant matrices $T^1\left((N'K') \times 1)\right)$, $T^2(1 \times N')$, and $T^3(NK \times N)$ such that the constraints for the master problem in step (i) can be written

$$(T^1u')T^3(vT^2) \leq (T^1u')c$$

As the mapping is linear and continuous, and the constraint forms a convex set, the mapping A^1 is closed. Zangwill [16] proves that the maximization operator is closed, call this A^2. Similarly, the constraints for the subproblems form closed maps, call then A^3, A^4, ..., $A^{N'+2}$, and equation (3.2) is trivially closed, call this map A^0. Therefore, the map A can be written as $A = A^0A^2A^{N'+2} \ldots A^2A^3A^2A^1$. The assumption that (v^1, u^1) is finite guarantees that the algorithm produces a sequence of bounded vectors, that is A is defined on a compact set. Closedness of A then follows from corollary 4.2.1 in [16, p. 96].

(iii) The penalty function.

$$\sum_{i=1}^{N} v^t(i) - \frac{1}{e} \sum_{i=1}^{N} \sum_{k=1}^{N} \left(\left[\sum_{j=1}^{N} \left(\delta_{ij} - \beta_p(i, j:k) \right) v^t(j) - c(i, k) \right]^+ \right)^2$$

monotonically decreases with t for some fixed value $e > 0$.

Remark. This result relates iterative aggregation for MDP's to the iterative algorithm for nonaggregated linear programs proposed in [7].

Bertsekas [3] has shown that there exists for linear programs an exact penalty function method such that for all e in the interval $(0, \bar{e})$, the penalty function algorithm converges. Let e be one such value. Using (3.2), the Lagrangean function for the master problem (3.1a) at iteration t+1 can be written as

$$\text{Maximize} \sum_{n=1}^{N'} z(n) - \sum_{n=1}^{N'} \sum_{k=1}^{K'} w(n, \ell) \left\{ \sum_{k \in A_\ell} \sum_{i \in S_n} \left(\frac{\lambda^t(n, \ell) u^{t-1}(i, k)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^{t-1}(i, k)} \right. \right.$$

$$\left. + \sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right)^+$$

$$\left. \left(\sum_{n=1}^{N'} z(n) \sum_{j \in S_n} \left(\delta_{ij} - \beta p(i, j:k) \right) \frac{v^t(j)}{\sum_{j \in S_n} v^t(j)} - c(i, k) \right) \right\}. \qquad (3.8)$$

At $w(n, \ell) \equiv \frac{1}{e}$ and at the trial value $z(n) = \sum_{i \in S_n} v^t(i)$, (3.8) reduces to:

$$\sum_{i=1}^{N} v^t(i) - \frac{1}{e} \sum_{n=1}^{N'} \sum_{\ell=1}^{K'} \left\{ \sum_{k \in A_\ell} \sum_{i \in S_n} \left(\frac{\lambda^t(n, \ell) u^{t-1}(i, k)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^{t-1}(i, k)} \right. \right.$$

$$\left. + \sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right)^+$$

$$\left. \left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right) \right\}. \tag{3.9}$$

At iteration t, let I^- denote the set of (i, k) such that (3.2) is nonpositive, and I^+ the set of (i, k) such that (3.2) is positive. Then (3.9) can be rewritten as:

$$\sum_{j=1}^{N} v^t(i) - \frac{1}{e} \sum_{n=1}^{N'} \sum_{\ell=1}^{K'} \left\{ \sum_{k \in A_\ell} \sum_{i \in S_n} \frac{\lambda^+(n, \ell) u^{t-1}(i, k)}{\sum_{k \in A} \sum_{i \in S_n} u^{t-1}(i, k)} \right.$$

$$\left. \left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right) \right\}$$

$$- \frac{1}{e} \sum_{(i, k) \in I^+} \left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right)^2$$

$$+ \frac{1}{e} \sum_{(i, k) \in I^-} \frac{\lambda^t(n, \ell) u^{t-1}(i, k)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^{t-1}(i, k)} \left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right) \tag{3.10}$$

If in the second term of (3.10),

$$\left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) v^t(j) - c(i, k) \right) \right)$$

were replace by

$$\sum_{n=1}^{N'} \left(\sum_{j \in S_n} \left(\delta_{ij} - \beta p(i, j:k) \right) z^t(n) \frac{v^{t-1}(i, j:k)}{\sum_{j \in S_n} v^{t-1}(j)} \right) - c(i, k)$$

then from the optimality of $z^t(n)$, $\lambda^t(n)$ in (3.1a), the entire term would be zero. However, (3.1b) insures that

$$\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) \leq \sum_{n=1}^{N'} \left(\sum_{j \in S_n} \left(\delta_{ij} - \beta p(i, j:k) \right) \frac{z^t(n) v^{t-1}(i, j)}{\sum_{j \in S_n} v^{t-1}(j)} \right)$$

and that their weighted sum (over $k \in A_\ell$, $i \in S_n$), weighted by

$$\frac{\lambda^t(n, \ell) u^{t-1}(i, k)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^{t-1}(i, k)}$$

are identical. Hence the second term in (3.10) is still identically zero. For $(i, k) \in \bar{I}$, by definition

$$\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \leq 0,$$

hence

$$\frac{\lambda^t(n, \ell) u^{t-1}(n, \ell)}{\sum_{k \in A_\ell} \sum_{i \in S_n} u^{t-1}(n, \ell)} \times \left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right) \leq 0.$$

These two results imply that (3.10) is less than or equal to:

$$\sum_{i=1}^{N} v^t(i) - \frac{1}{e} \sum_{i=1}^{N} \sum_{k=1}^{K} \left[\left(\sum_{j=1}^{N} \left(\delta_{ij} - \beta p(i, j:k) \right) v^t(j) - c(i, k) \right)^+ \right]^2 . \qquad (3.11)$$

Moreover, this implies for $w(n, \ell) \equiv \frac{1}{e}$, $\max_z L(z, w)$ occurs at $z(n) = \sum_{i \in S_n} v^t(i)$. Therefore $L(z^{t+1}, \lambda^{t+1}) \leq L(z^{t+1}, \frac{1}{e}) \leq L(z^t, \frac{1}{e}) \leq (3.11)$. The optimality of z^{t+1}, λ^{t+1} in the master LP (3.1a) and the fact that v^{t+1} solves the N' problems (3.1b) guarantee that the penalty function evaluated at v^{t+1} is less than or equal to $L(z^{t+1}, \lambda^{t+1})$.

(iv) The map A is defined on a compact set.

Suppose A is not bounded from above. Then (v^t, u^t) for some t must approach infinity. This implies that the penalty function at iteration t is unbounded. However, by assumption, (v^1, u^1) are finite, and the penalty function at iteration 1 is bounded. Moreover, from part (iii) of the proof: Penalty function at iteration $1 \geq$ penalty function at iteration $t \geq 0$. This contradicts the assumption that A is not bounded.

□

When steps (i)-(iv) of the iterative aggregation process are used only every k^{th} iteration, and the alternatives (3.3), (3.4), or (3.5) are used at all other iterations, proofs of convergence follow closely the proof of theorem 3.2 to derive the conditions necessary for Zangwill's other convergence theorems. Intuitively, one full step of successive approximations still is computed infinitely often if the algorithm does not find a fixed point. As long as the intermediate steps do not force the value function v and the dual variables u in undesirable directions, the algorithm converges since successive approximations converges when applied to MDP's.

Finally, it is conjectured that convergence can be proven in an analogous manner to theorem 3.2 if only some subset of the dual variables are adjusted by equation (3.2) at each iteration. (This is in the spirit of several relaxation algorithms [2, 9].) For example, one partition at a time could be updated each iteration using equation (3.2).

Theorem 3.2 can also be proven using the augmented Lagrangean in part (iii) instead of the penalty function. As the dual update (3.2) is a method of multipliers update, the algorithm approximates the maximum v for each u^{t+1} in the augmented Lagrangean. Sufficient conditions for such approximate procedures to converge are given in Rockefellar [10].

Clearly the algorithm need not be run until it converges if approximate solutions are satisfactory. Since at the end of each iteration π_n^t describes a nonrandomized policy that can be followed, any of the bounds for aggregate LP's or MDP's given in [8, 15, 18] can be used as stopping rules.

4. CONCLUSION

An iterative aggregation procedure for MDP's has been presented which converges globally to an optimal value function and to optimal dual variables. The process requires less in-core storage at any point than does solving the full MDP. However, each iteration requires at least the computational equivalent of one iteration of successive approximations. Convergence should be more rapid using the iterative aggregation process.

To reduce the computational burden, several alternative procedures are presented at key steps. Convergence has not been proven when these procedures are used; however, if the full iterative aggregation process is used every k^{th} iteration, then again the algorithm converges globally.

There should exist a more efficient computational method for updating the dual variables at each iteration, a method which converges globally. Improvements in this area should lead to truly efficient means for solving large-scale MDP's.

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ESTIMATES OF THE CATCH AND EFFORT BY FOREIGN TUNA LONGLINERS AND BAITBOATS IN THE FISHERY CONSERVATION ZONE OF THE CENTRAL AND WESTERN PACIFIC, 1965-77

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INTRODUCTION

Since passage of the Fishery Conservation and Management Act (FCMA), there has been an increasing need for information on the fishing activity of foreign vessels in the U.S. Fishery Conservation Zone (FCZ) and other areas of U.S. interest. A knowledge of foreign catch and fishing effort is essential for analysis of management policies, for appraisal of fishery development potentials, and for planning of fishery surveillance and enforcement activities.

In the case of billfishes, foreign catches in the FCZ are made by tuna longline vessels of Japan, Taiwan, and the Republic of Korea. The vessels usually direct their effort toward tunas and catch billfishes only incidentally.[1] The primary purpose of this report is to summarize available information on the nominal effort and the catch of tunas and billfishes by these foreign longline fleets in the FCZ of the central and western Pacific during the period 1965-77. In addition, the report presents estimates of the effort and tuna catch by Japanese baitboats fishing around Hawaii, Guam, the Northern Marianas, and other U.S. possessions.

In the following section the data sources and their characteristics and limitations are described. Then the data summarization and estimation procedures are discussed. Finally, the tables of resulting catch and effort statistics are presented, and suggestions are given for improving and updating the information.

DATA SOURCES

The estimates of foreign catch and effort were based on a variety of statistical sources. In this section the sources are systematically identified and described. For reference purposes a data set name is assigned to each source (Table 1).

Japanese Tuna Longline Statistics by 1° Square [Data Set D1]

This data set consists of records of Japanese tuna longline nominal effort (hooks fished and days fished) and associated catches of tuna and billfish species (number of fish) by month and 1° square. It covers only those 1° squares in the central and western Pacific overlapping the FCZ in Hawaii, American Samoa, and Guam, and only the years 1971-75. The data are unpublished, and were made available to the National Marine Fisheries Service (NMFS) by the Fisheries Agency of Japan. The data were provided in unraised form; estimates of total catch and effort in each time-area stratum were made by multiplying the sample data by raising factors taken from appropriate issues of "Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fishery" published by the Fisheries Agency of Japan.

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[1]Under the FCMA, the U.S. claims jurisdiction over billfishes in the FCZ, but not over tunas.

Japanese Tuna Longline Statistics by 5° Square
[Data Set D2]

This data set consists of the well-known published statistics of monthly catch and effort by Japanese tuna longliners in 5° square areas. It is available throughout the range of the Japanese fleet in the Pacific for 1962-77. The data are published in the reference cited above. The catch and effort totals for a 5° square are equal to the sum of these statistics over all 1° squares in the 5° block, i.e., data set D2 may be considered an aggregation of data set D1. The statistics are published in raised form since 1967, and unraised form for the earlier years.

Taiwanese Tuna Longline Statistics by 5° Square
[Data Set D3]

This data set contains monthly statistics on catch of tunas and billfishes (number of fish and weight of fish) and effort (hooks fished) of Taiwanese high-seas longliners by 5° square throughout the range of the fleet. Data for 1967 through 1977 are available, provided to us by the Taiwan Fisheries Bureau. Unraised sample statistics were provided by Taiwan and then raised. Annual summaries of the unraised statistics and raising factors are published by the Taiwan Fisheries Bureau in "Annual Catch Statistics of Taiwan's Tuna Longline Fishery."

American Samoa Tuna Longline Statistics
[Data Set D4]

This unpublished data set contains the catch (number of fish) and effort (hooks fished and days fished) by sampled Taiwanese, Korean, and Japanese longliners based at Pago Pago and operating primarily in the South Pacific. The statistics are extracted from logbooks of daily fishing activity submitted by vessel captains to the Office of Marine Resources of the Government of American Samoa, and are available for the period 1960 through 1976.[2] The logbook records give daily effort and catch by species along with the midday position of the vessel. Not all vessels submit logbooks, so raising factors are necessary to project the sample catch and effort to the entire fleet. Computation of raising factors is facilitated by a second set of data for vessels based at Pago Pago. These are the records of cannery landings made available to us by Star-Kist Samoa, Inc. and Van Camp Sea Food Co. They provide direct estimates of the tonnage of fish landed by all vessels, those appearing in the logbook statistics and those not covered in the catch and effort sampling.

Japanese Baitboat Statistics
[Data Set D5]

This data set consists of catch and effort records of the Japanese baitboat fleet operating in the central and western Pacific. Catch (in metric tons) and nominal effort (vessel days) are published annually by

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[2]Data for 1977 and 1978 are available, but are incomplete, so catch and effort estimates are possible only through 1976.

the Fisheries Agency of Japan in "Annual Report of Effort and Catch Statistics by Area, Japanese Skipjack Baitboat Fishery." The published records are given by 1° square and 10-day interval. In our analysis we used summaries by month and 1° square for the years 1970-77. On the average, the baitboat statistics cover about 80% of the actual catch and effort, so we raised the statistics by a factor of 1.25.

PROCEDURES AND ASSUMPTIONS

Boundaries

Figure 1 shows the boundaries we used for computing catch and effort within the FCZ around the Hawaiian Islands, American Samoa, Guam, the Northern Mariana Islands, and the various minor U.S. possessions, e.g., Wake Island, Johnston Atoll, Howland Island, Baker Island, Kingman Reef, Palmyra Island, and Jarvis Island. Boundaries are essentially as given in the Federal Register (vol. 42(44)-7 March 1977; vol. 43(7)-11 January 1978), except that we included Kingman Reef as a U.S. territory, and we assumed straight-line closures around parts of Jarvis Island, Howland Island, and Baker Island. Similarly, we drew a provisional boundary (dashed line) around the northern and northeastern part of the American Samoa FCZ (including Swains Island) and assumed a median-line separation between American Samoa and the Tokelau Islands.

The provisional boundaries drawn here were adopted to provide a basis for catch computations only. They are not to be construed as legal limits, nor do they prejudice any U.S. position regarding disputed claims or jurisdictional conflicts in the Pacific.

In addition to computing catches of tunas and billfishes and nominal effort within each of the 200-mile zones, or within the entire FCZ areas, we also computed these statistics for other more restricted zones around Hawaii, American Samoa, Guam, and the Northern Mariana Islands (Figures 2, 3, and 4). The boundaries adopted in these cases were selected primarily for illustrative purposes, and are not intended to reflect any preference with respect to fishery management policy. For the Hawaiian Islands, the chain was split into the main Hawaiian Islands and the Northwestern Hawaiian Islands (NWHI), with the dividing line at 161°W longitude (between Niihau Island and Nihoa Island). Catches and effort were computed within 50 miles, 100 miles, and 200 miles of the islands in each sector (Figure 2).

In the case of Guam, the Northern Mariana Islands, and American Samoa, a 50-mile zone was drawn and catches and effort were estimated for these zones as well as for the entire FCZ (Figures 3 and 4).

Apportioning

Estimates of nominal effort and the catch of tunas and billfishes were made by adding up the appropriate statistics for all 1° squares or 5° squares, or parts thereof, falling within the boundaries of the area of interest. In instances where the boundary of an area cut through a square, the distribution of catch and effort within the square was assumed to be homogeneous, and a part of the square's catch and effort was added to the area totals according to the proportion of the square falling within the area boundaries.

One-degree square statistics (D5) were used to estimate effort and catch of Japanese baitboat vessels around the Hawaiian Islands, Guam, and the Northern Marianas, and other U.S. possessions. One-degree square data were also used for Japanese longline catch and effort around Hawaii and Guam during 1971-75 (D1), and for all of the American Samoa longline catch and effort estimates (D4). In every other case 5° square statistics were used.

Raising Factors

The tuna longline fishery statistical systems of Japan and Taiwan are sampling systems, which means that there is not a complete enumeration or accounting of the catch and effort. Instead, only a sample of the logbooks from vessels operating in the Pacific is covered. The sample catch and effort statistics must be expanded to produce estimates of total catch and effort, using raising factors. Sampling coverage for Japanese tuna longline vessels is relatively high (Table 2). Coverage is proportional to size of the vessel for Japan-based boats. The raising factors for Japanese statistics are available only on an annual and Pacific-wide basis.

In the case of Taiwanese longliners, raising factors are available monthly (Table 3), but for all sizes of vessels combined and for the entire Pacific until 1977. Beginning in 1977, factors were computed by month and 5° square. Coverage of Taiwanese vessels is very low, being generally less than 20%.

For vessels based at Pago Pago, coverage is variable. From 50 to 95% of the vessels landing at Pago Pago submit logbooks containing detailed statistics on catch and effort. Since 1970 Korean vessels have been covered more completely than longliners from Taiwan, and for vessels of both flags the coverage rate has decreased considerably from the levels maintained during the 1960's.

In our initial analyses we computed raising factors for American Samoa as the product of (1) estimated average weight, taken from Taiwanese longline data for the area, and (2) ratio of landings by all vessels to landings by those vessels included in the logbook sampling. However, when these factors were applied to the sampled numerical catches the resulting estimates of total catch in weight were in most cases less than the recorded total cannery landings. This could happen if our average weight estimates were too low, or the proportion of the catch actually landed and recorded in cannery records was greater for sampled longliners [those submitting logbooks] than for other vessels, or the logbook catch data for sampled vessels was incomplete. Since no detailed information was available for evaluating these possible sources of error, we carried out the catch and effort estimation in a different manner. First we adjusted the billfish landings during each quarter to account for billfish which were landed at one of the canneries but did not appear in the statistics available to us. This adjustment was made assuming the ratio of billfish landings to tuna landings was the same at the two canneries. It was done separately for each vessel nationality. Next, the adjusted landings were multiplied by other correction factors to convert from dressed weights to round weights. These correction factors were 1.15 for yellowfin tuna, 1.16 for bigeye tuna, 1.2 for billfishes, and 1.0 for albacore and wahoo. Then, final correction factors were

computed by year, species (except billfishes were combined), nationality, and cannery as the ratios of total landings (adjusted as indicated above) to the corresponding total numbers of fish caught by the sampled vessels. These final factors were multiplied by the individual monthly catches in 1° cells (D4) and, after apportioning in the manner described above, the products were summed within each zone of interest. This procedure was followed for billfishes, albacore, yellowfin, bigeye, and wahoo. Thus for these species we assumed the total adjusted cannery landings were accurate and accounted for all fish caught. The remaining species are skipjack and bluefin tunas. These are very minor constituents of the catch and are neglected in the canneries' summary statistics. Therefore, for these species we estimated total catches in weight by simply multiplying the observed catches in number of fish by estimated average weights of 6.0 kg (skipjack tuna) and 52.6 kg (bluefin tuna).

The cannery statistics should account for virtually all tuna and billfish taken by the longliners based at Pago Pago, although small amounts which are not landed there may go unrecorded.

Adjustment factors were also used to estimate the total nominal fishing effort by American Samoa longliners. These were computed by nation, cannery, and year as the ratio of total vessel days of fishing by all vessels covered in the statistics of cannery landings to the number of vessel days fished by longliners appearing in the logbook sampling.

As mentioned in an earlier section, a raising factor of 1.25 was used to expand the sample Japanese baitboat catch and effort statistics.

Average Weights

The basic longline catch statistics of data sets D1, D2, D3, and D4 are expressed in number of fish taken. (Weight of catch is also reported by Taiwanese longliners (data set D3), but this information was available to us only in aggregate form.)

Longline catches in weight for Hawaii, Guam, the Northern Marianas, and minor U.S. possessions were estimated by multiplying catch in number by appropriate values of average weight. The average weight statistics came from two sources:

(1) Average weights for catches in the Hawaiian FCZ and around Johnston Atoll were based on annual statistics from the Hawaiian domestic longline fleet, provided by the United Fishing Agency, Ltd. of Honolulu, Hawaii and the Hawaii Division of Fish and Game (Table 4).

(2) The average weights of tunas and billfishes taken elsewhere by longliners of Taiwan and Japan were estimated from data obtained from the Fisheries Agency of Japan and from publications of the Taiwan Fisheries Bureau (Table 5).

Accuracy

Assuming the basic statistics we used are correct, the accuracy and reliability of our catch and effort estimates depend on two main conditions: (1) homogeneity of catch and effort distribution within the smallest space-time stratum under consideration, and (2) uniformity of sample coverage in time and space.

The first condition does not generally hold, as may be demonstrated by comparing estimates based on 5° square data with corresponding estimates based on 1° square statistics. A 5° breakdown of catch and effort statistics is simply too coarse for an accurate, detailed spatial analysis of fishing activity within the FCZ. Estimates based solely on 5° square data should therefore be viewed circumspectly.

Even greater problems are created by departures from the second condition. The use of a common ocean-wide raising factor may be perfectly adequate for ocean-wide estimates, but may lead to serious distortion in estimates of catch and fishing effort in small subareas of the ocean. Steps have recently been taken by the Taiwan Fisheries Bureau to improve their sampling system so that individual raising factors are available by month and 5° square.

Considering these factors, it is obvious that one cannot put a great deal of confidence in some of the catch and effort estimates. Nevertheless, these estimates are the best currently available.[3]

THE CATCH AND EFFORT TABLES

The estimated nominal effort and catch statistics are presented in Tables 6 through 91. Catches are stated in metric tons (mt). Effort is given in vessel days. In the case of Taiwan longline effort outside the American Samoa area, the effort figures were estimated by dividing the number of hooks fished by 2,000, which is approximately the average number of hooks fished per vessel day. In other cases effort was computed directly. An asterisk in the effort section denotes effort greater than zero but less than 1 vessel day. An asterisk in the catch columns means some fish were caught but less than 1 mt.

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[3]A similar report has been released by the South Pacific Commission, Noumea, New Caledonia. See: Klawe, W. L. 1978. Estimates of catches of tunas and billfishes by the Japanese, Korean, and Taiwanese longliners from within the 200-mile economic zone of the member countries of the South Pacific Commission; SPC Occasional Paper No. 10

Longline catch estimates are presented for the following species:

albacore	Thunnus alalunga
yellowfin tuna	T. albacares
bigeye tuna	T. obesus
bluefin tuna[4]	T. thynnus
skipjack tuna	Katsuwonus pelamis
blue marlin	Makaira nigricans
black marlin	M. indica
striped marlin	Tetrapturus audax
swordfish	Xiphias gladius
sailfish	Istiophorus platypterus
shortbill spearfish	T. angustirostris

In addition, catches of wahoo, Acanthocybium solandri, are given for the longline vessels based at Pago Pago. Note that all tables of longline catches give a combined estimate of the catch of sailfish and shortbill spearfish, since these species are not separated in the records submitted by either Japanese or Taiwanese longline fishermen, or in the logbook records of foreign vessels based at American Samoa.

The Japanese baitboat catch estimates are given for albacore, yellowfin, bigeye, bluefin, and skipjack. In addition, catches of frigate tuna, Auxis thazard, and miscellaneous species (others) are estimated.

IMPROVING ESTIMATES

We have identified several possible shortcomings in the estimates of catch and effort within specified geographical areas. The estimates may be improved by (1) using more detailed longline statistics than the usual 5° square summaries which are now generally available. In the case of longline vessels based at Pago Pago daily fishing logs are available to us. But the official, published longline statistics of Taiwan, Japan, and Korea are only by 5° square. More detailed Japanese data are available in unpublished form; (2) using more detailed raising factors, instead of the Pacific-wide factors now employed. Taiwan has taken steps to refine this aspect of their longline catch estimation--it would be useful if other nations also instituted such improvements; (3) using more accurate statistics on average weight. Temporal and spatial variation should be taken into account, and better size statistics should be sought from unpublished sources; (4) a more complete analysis of the American Samoa-based fishery. The estimates given here reflect only the landings reported by the two tuna canneries operating in Pago Pago. The records available to us do not take into account small amounts of fish landed and sold through other channels. A more extensive study of American Samoa fishery statistics should be undertaken so that a complete accounting can be made of all fish caught or landed in that area of the FCZ.

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[4]In the case of vessels based at American Samoa, the negligible bluefin catch is mostly southern bluefin tuna (T. maccoyii) taken in the southern extremity of the South Pacific albacore grounds.

The estimates reported here do not present a complete picture of foreign tuna and billfish catches in the FCZ, since except for American Samoa-based vessels no Korean statistics were considered. Korean tuna longliners (mostly sashimi boats) are known to fish in all areas of the FCZ, and while extensive catch and effort data are available, we are not yet able to answer key questions about appropriate raising factors, sampling procedures, and reliability. Until such considerations can be dealt with, we will refrain from using the Korean longline statistics.

In addition to problems with the Korean longline statistics we have been unable to evaluate possible Korean baitboat catches in the FCZ. No information is available to us on this subject.

Mention should be made of fishing inside the Hawaii FCZ by longline vessels based in American Samoa. Such catches, mainly by Korean boats, are minor, but the frequency of such visits has been increasing in recent years. Information on this subject is being compiled for publication in a separate report.

A comment is also needed concerning the possibility that some small catch in the American Samoa FCZ is made by longliners not based in Pago Pago and therefore not monitored in the American Samoa logbook system. Catches by Japanese vessels can be ruled out, since Japanese Government statistics show no effort in that area by her vessels since 1971. But the question remains unanswered for Taiwan and Korea.

Finally, the published catch and effort records examined in this analysis do not cover any Japanese baitboats or longliners under 20 gross tons, or any Taiwanese longliners under 50 gross tons. This is of no consequence except around Guam and the Northern Marianas, where some small Taiwan-based Taiwanese longliners and small Japanese longliners may be operating. Also neglected are any Japanese purse seine catches of tunas in this area; however, these are negligible, as most purse seine activity is south of this region.

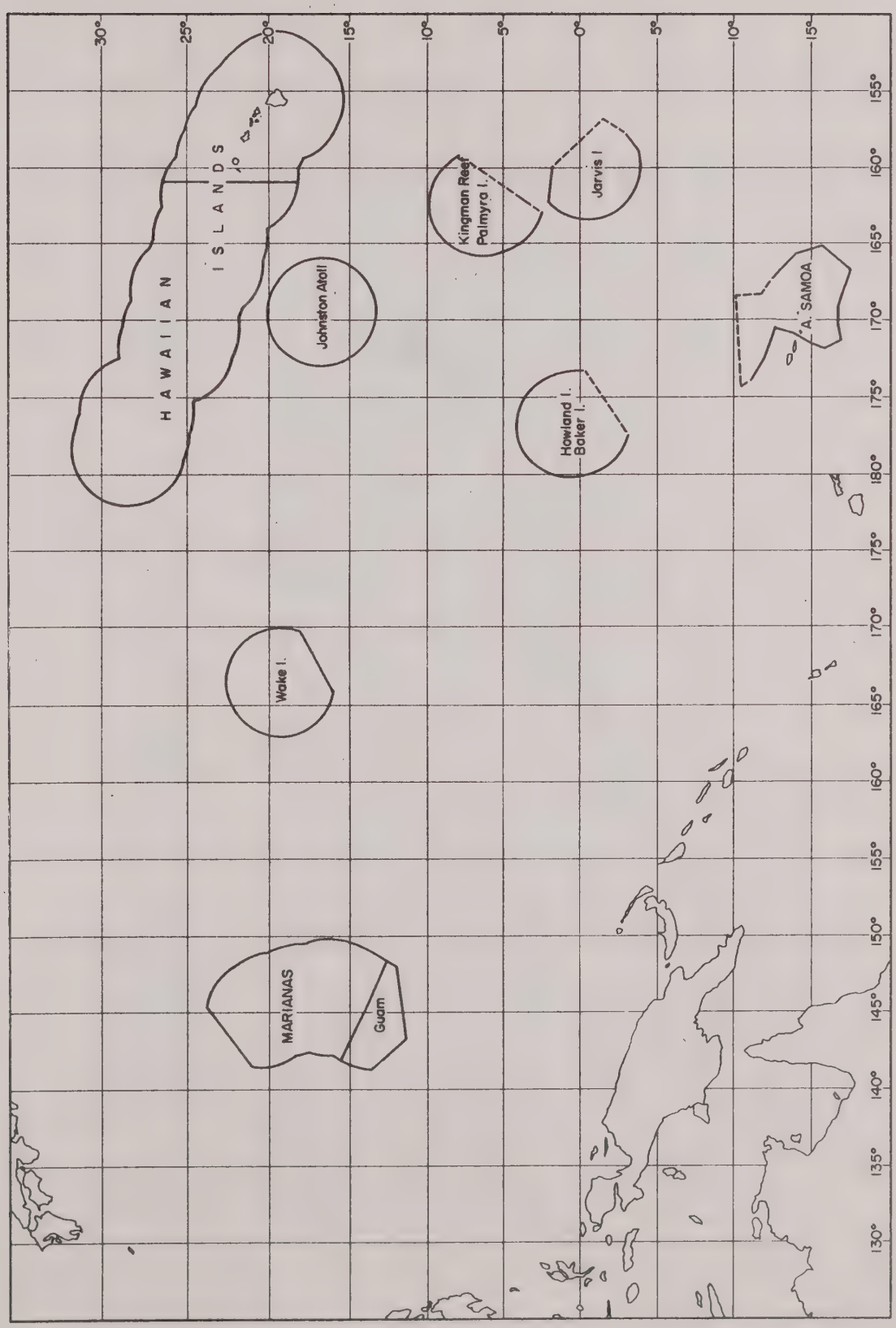

Figure 1.--Boundaries of the Fishery Conservation Zone around Hawaii, American Samoa, Guam, the Northern Mariana Islands, and other U.S. possessions. [See text for explanation.]

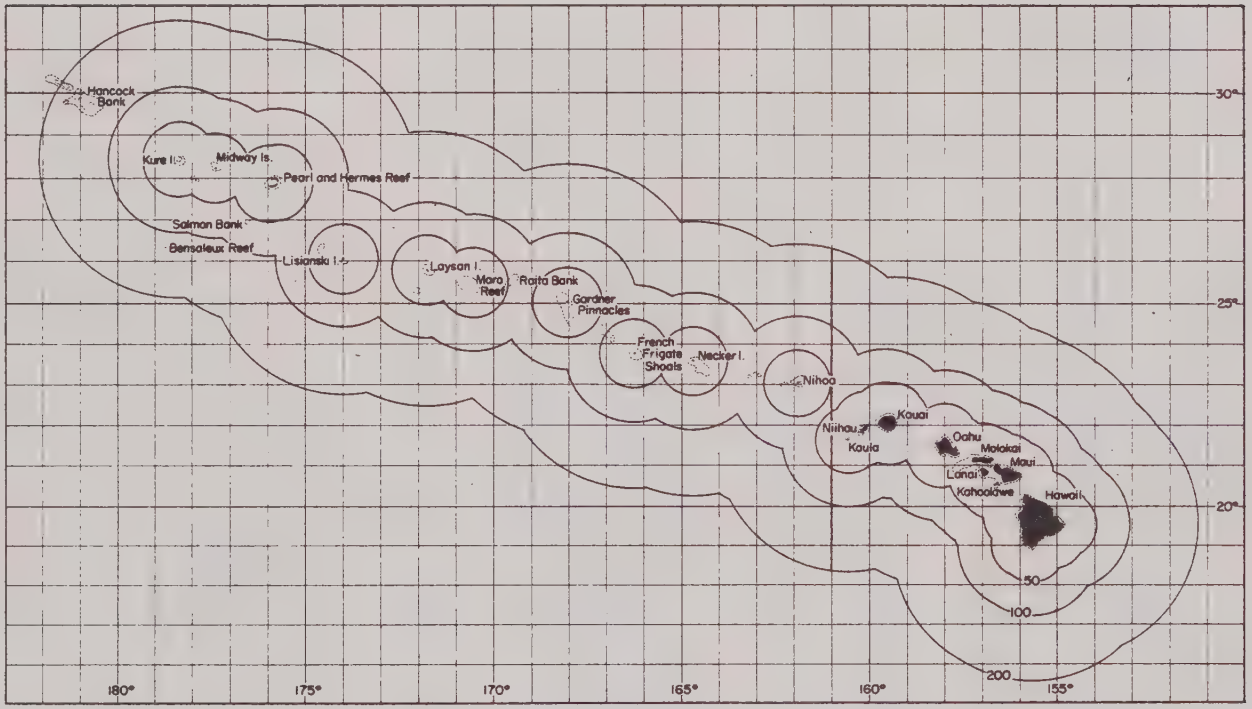

Figure 2.--The 50-, 100-, and 200-mile zones around the Hawaiian Islands.

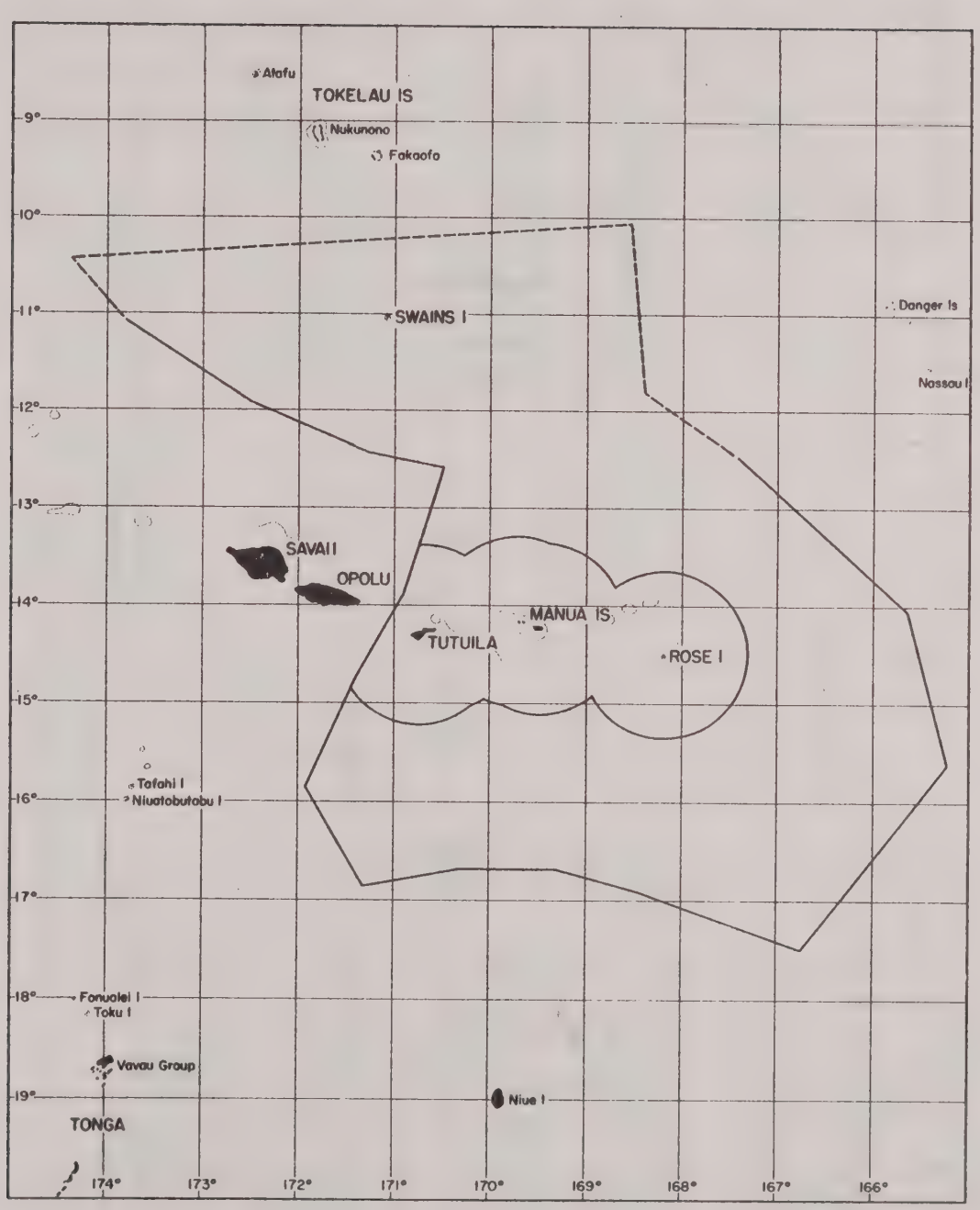

Figure 3.--The 50-mile limits and the Fishery Conservation Zone around American Samoa.

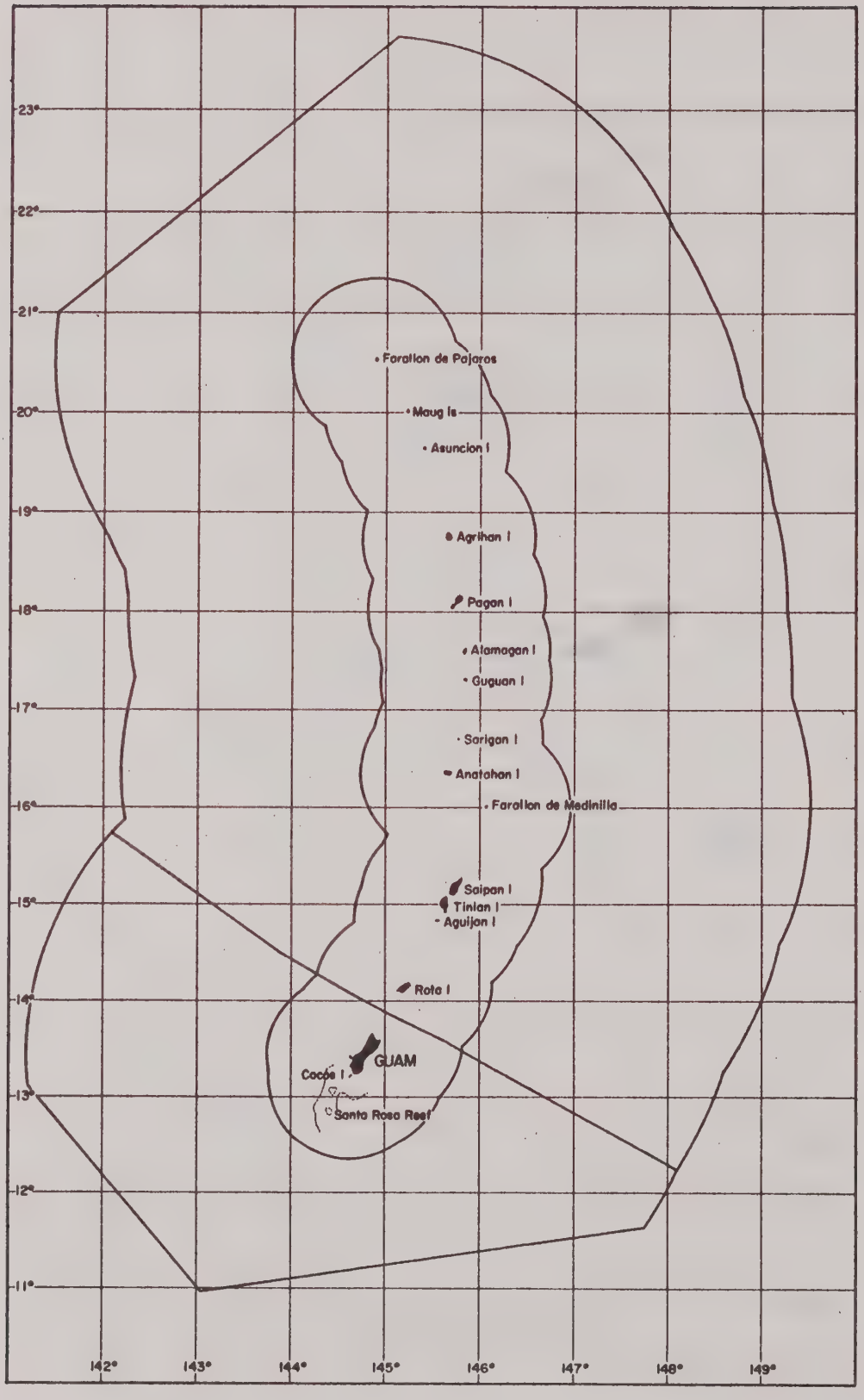

Figure 4.--The 50-mile limits and the Fishery Conservation Zone around Guam and the Northern Mariana Islands.

Table 1.--Description of data sets.

Data set	Type of data	Nationality	Year available	Spatial and temporal detail	Source of data
D1	Sample catch (number of fish) by species; nominal effort (hooks, vessel days)	Japan	1971-75	1° square, by month, size of vessel, bait type	Fisheries Agency of Japan (Unpublished)
D2	Catch (number of fish) by species; nominal effort (hooks, vessel days)	Japan	1962-77	5° square, by month, size of vessel, bait type	"Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fishery," published by Fisheries Agency of Japan
D3	Catch (number of fish) by species; nominal effort (hooks)	Taiwan	1967-77	5° square, by month	"Annual Catch Statistics of Taiwan's Tuna Longline Fishery," published by Taiwan Fisheries Bureau
D4	Catch (number of fish) by species; nominal effort (hooks, vessel days)	Japan, Taiwan, Korea	1960-76	By midday position for each sampled vessel based at Pago Pago	Office of Marine Resources, Government of American Samoa (Unpublished)
	Landings (pounds) at Pago Pago by species (tuna), or combined (billfish); nominal effort (vessel days)		1954-76	By month	Van Camp Sea Food Co., Star-Kist Samoa, Inc. (Unpublished)
D5	Sample catch (metric tons) by species; nominal effort (vessel days)	Japan	1969-77	1° square, by 10-day interval, effort by vessel tonnage class	"Annual Report of Effort and Catch Statistics by Area, Japanese Skipjack Baitboat Fishery," published by Fisheries Agency of Japan.

Table 2.--Hundreds of vessel days of nominal effort (top figures) and appropriate raising factors (bottom figures) for Japanese tuna longline vessels, 1965-77.

Year	Japan-based vessels (gross tons) 20-50	50-100	100-200	>200	Motherships with catcher boats	Foreign-based vessels (Pacific)
1965	718	- 442 -		425	22	101
	1.41	1.99	1.99	1.24	1.27	2.01
1966	621	- 515 -		473	9	90
	1.27	1.81	1.81	1.18	1.17	1.30
1967	745	266	196	395	7	105
	1.68	2.10	1.44	1.19	1.14	1.94
1968	616	242	209	417	7	59
	1.74	2.02	1.50	1.26	1.16	1.51
1969	579	278	237	472	18	30
	2.10	1.93	1.67	1.16	1.21	2.34
1970	395	292	205	527	16	29
	1.73	1.74	1.39	1.02	1.08	2.45
1971	316	344	198	519	3	22
	2.12	1.81	1.48	1.22	1.63	5.70
1972	211	385	178	613	1	15
	2.43	2.04	1.47	1.18 / 1.23 [1]	1.75	1.30
1973	151	463	157	682	4	4
	2.24	1.95	1.72	1.13 / 1.44 [1]	1.13	1.75
1974	124	594	124	628	1	0
	2.25	1.84	1.47	1.16 / 1.28 [1]	1.20	--
1975	98	612	93	509	2	0
	1.84	1.71	1.42	1.13 / 1.32 [1]	1.00	--
1976	95	663	118	735	3	0
	1.35	1.25	1.10	1.13 / 1.10 [1]	1.00	--
1977	80	675	112	700	1	0
	1.23	1.20	1.24	1.04 / 1.02 [1]	1.00	--

[1]Upper raising factor is for vessels landing in Shizuoka and Kochi Prefectures. Lower factor is for other vessels.

Table 3.--Raising factors for Taiwan's tuna longline statistics (Pacific Ocean).

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
January	9.09	3.48	6.21	4.27	2.36	4.40	4.36	7.15	16.37	9.53
February	9.09	3.48	6.21	4.53	2.47	3.67	5.73	7.26	12.25	9.53
March	9.09	3.48	6.21	3.91	2.73	4.59	6.21	10.15	7.61	9.53
April	9.09	3.48	6.21	3.55	2.34	3.89	8.25	10.48	6.21	8.04
May	9.09	3.48	6.21	3.83	3.23	4.58	7.62	7.54	5.90	8.04
June	9.09	3.48	6.21	3.04	3.23	5.05	5.84	8.86	4.54	8.04
July	9.09	3.48	6.21	2.43	3.20	3.91	6.65	8.77	4.37	8.98
August	9.09	3.48	6.21	2.44	3.42	3.98	8.31	14.24	5.26	8.98
September	9.09	3.48	6.21	2.70	3.03	4.62	5.49	13.42	4.46	8.98
October	9.09	3.48	6.21	2.56	4.47	3.78	5.57	13.33	5.56	11.71
November	9.09	3.48	6.21	2.43	3.51	3.85	5.13	11.30	6.06	11.71
December	9.09	3.48	6.21	2.67	4.05	4.18	6.05	11.93	6.83	11.71

Note: Raising factors for 1977 were computed by month and 5° square. However, at the time this table was prepared, monthly ocean-wide averages were not available. The annual average raising factor for the Pacific was 3.84 for 1977, indicating a considerable improvement in sampling coverage.

Table 4.--Estimated average weights (kg) used in computing longline catches in the FCZ around the Hawaiian Islands and Johnston Atoll. (From data supplied by Hawaii Division of Fish and Game and United Fishing Agency.)

Year	Albacore	Yellowfin tuna	Bigeye tuna	Bluefin tuna	Skipjack tuna	Blue marlin	Black marlin	Striped marlin	Swordfish	Sailfish and spearfish
1965	25	49	46	200	6	89	65	29	84	16
1966	24	50	54	200	6	115	65	25	84	16
1967	24	51	50	200	5	102	65	28	84	16
1968	26	52	45	200	5	92	65	30	84	15
1969	25	50	47	200	4	90	65	30	84	16
1970	25	48	44	200	4	83	65	28	84	16
1971	25	47	43	200	5	97	65	30	84	16
1972	26	48	45	200	7	89	65	32	84	17
1973	23	49	48	200	6	70	65	26	84	18
1974	24	49	39	200	5	66	65	28	84	16
1975	23	45	43	200	4	77	65	28	84	17
1976	26	50	46	200	5	89	65	30	84	16
1977	25	49	46	200	5	89	65	29	84	16

Table 5.--Estimated average weights (kg) used in computing longline catches in the FCZ around Guam, the Northern Marianas, and some other U.S. possessions in the Pacific. (From data supplied by Fisheries Agency of Japan and Taiwan Fisheries Bureau.)

Year	Albacore	Yellowfin tuna	Bigeye tuna	Bluefin tuna	Skipjack tuna	Blue marlin	Black marlin	Striped marlin	Swordfish	Sailfish and Spearfish
Guam and Northern Marianas										
1975	25	28	38	237	5	55	79	34	30	22
1976	24	30	39	237	5	55	79	34	30	22
1977	24	30	37	237	5	55	79	28	30	22
Other years	24	29	38	237	5	55	79	32	30	22
Wake Island										
1975	26	30	39	184	5	50	79	30	33	28
1976	27	35	43	184	5	50	79	30	33	28
1977	27	35	42	184	5	56	91	22	39	28
Other years	27	33	41	184	5	52	83	27	35	28
Howland Island, Baker Island, Palmyra Island, Kingman Reef, and Jarvis Island										
All years	18	25	27	53	5	47	60	39	56	25

Table 6.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1965.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	18	7	4	56	30	12	74	37	16
February	18	7	3	27	5	1	45	12	4
March	5	2	1	61	21	7	66	23	8
April	19	8	3	45	27	10	64	35	13
May	169	66	30	291	147	53	460	213	83
June	47	26	12	412	218	75	459	244	87
July	0	0	0	80	46	18	80	46	18
August	17	6	3	9	2	*	26	8	3
September	2	1	*	3	*	*	5	1	*
October	2	1	*	77	35	14	79	36	14
November	9	3	1	113	22	7	122	25	8
December	61	25	12	153	39	16	214	64	28
Total	367	152	69	1327	592	213	1694	744	282
				Annual catch[2]					
Albacore	6	3	2	133	19	7	139	22	9
Yellowfin tuna	131	54	25	330	158	59	461	212	84
Bigeye tuna	330	122	55	412	133	49	742	255	104
Bluefin tuna	3	1	1	3	2	1	6	3	2
Skipjack tuna	2	1	1	7	4	1	9	5	2
Total tunas	472	181	84	885	316	117	1357	497	201
				Annual catch[2]					
Blue marlin	54	25	11	245	126	45	299	151	56
Striped marlin	113	54	25	775	406	145	888	460	170
Swordfish	5	3	1	67	24	9	72	27	10
Black marlin	2	1	*	5	2	1	7	3	1
Spearfish & sailfish	10	4	2	24	12	4	34	16	6
Total billfishes	184	87	39	1116	570	204	1300	657	243

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 7.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1966.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	9	2	1	62	5	2	71	7	3
February	20	5	1	88	28	12	108	33	13
March	20	7	3	35	11	4	55	18	7
April	60	22	10	7	1	1	67	23	11
May	33	11	5	115	55	20	148	66	25
June	168	59	24	22	10	3	190	69	27
July	30	10	3	2	1	*	32	11	3
August	0	0	0	2	1	1	2	1	1
September	6	1	1	66	4	1	72	5	2
October	4	2	1	90	7	1	94	9	2
November	2	1	*	131	16	5	133	17	5
December	1	1	*	108	6	1	109	7	1
Total	353	121	49	728	145	51	1081	266	100
				Annual catch[2]					
Albacore	1	*	*	256	24	8	257	24	8
Yellowfin tuna	67	21	9	102	17	6	169	38	15
Bigeye tuna	502	164	64	487	58	19	989	222	83
Bluefin tuna	0	0	0	1	*	0	1	*	0
Skipjack tuna	3	1	*	4	2	1	7	3	1
Total tunas	573	186	73	850	101	34	1423	287	107
				Annual catch[2]					
Blue marlin	77	27	11	50	14	5	127	41	16
Striped marlin	44	15	7	118	38	13	162	53	20
Swordfish	9	3	1	83	10	4	92	13	5
Black marlin	1	*	*	2	1	*	3	1	*
Spearfish & sailfish	9	3	1	10	2	1	19	5	2
Total billfishes	140	48	20	263	65	23	403	113	43

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 8.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1967.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	1	0	0	140	14	4	141	14	4
February	10	2	*	83	8	2	93	10	2
March	26	9	4	69	11	4	95	20	8
April	51	22	10	144	71	27	195	93	37
May	354	179	96	115	56	21	469	235	117
June	173	80	38	156	84	29	329	164	67
July	24	9	4	16	5	2	40	14	6
August	1	1	*	10	4	1	11	5	1
September	2	1	1	38	1	*	40	2	1
October	4	1	1	53	6	2	57	7	3
November	20	6	2	179	55	21	199	61	23
December	9	2	1	73	12	5	82	14	6
Total	675	312	157	1076	327	118	1751	639	275
				Annual catch[2]					
Albacore	12	6	3	436	47	14	448	53	17
Yellowfin tuna	90	45	23	148	64	24	238	109	47
Bigeye tuna	678	262	117	570	145	54	1248	407	171
Bluefin tuna	0	0	0	1	*	0	1	*	0
Skipjack tuna	2	1	*	2	1	*	4	2	*
Total tunas	782	314	143	1157	257	92	1939	571	235
				Annual catch[2]					
Blue marlin	112	53	27	85	41	15	197	94	42
Striped marlin	244	140	77	379	176	65	623	316	142
Swordfish	28	15	8	147	27	9	175	42	17
Black marlin	2	1	1	1	1	*	3	2	1
Spearfish & sailfish	22	11	6	10	4	2	32	15	8
Total billfishes	408	220	119	622	249	91	1030	469	210

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 9.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1968.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	12	4	2	198	43	16	210	47	18
February	26	10	4	183	45	16	209	55	20
March	33	15	7	134	76	32	167	91	39
April	382	137	57	57	33	12	439	170	69
May	237	108	49	413	234	85	650	342	134
June	148	78	40	171	87	29	319	165	69
July	3	2	1	26	15	6	29	17	7
August	0	0	0	0	0	0	0	0	0
September	2	*	*	35	1	*	37	1	*
October	12	3	1	113	28	9	125	31	10
November	47	23	10	268	114	43	315	137	53
December	72	29	13	146	36	13	218	65	26
Total	974	409	184	1744	712	261	2718	1121	445
				Annual catch[2]					
Albacore	22	10	5	646	147	52	668	157	57
Yellowfin tuna	217	94	43	232	120	43	449	214	86
Bigeye tuna	658	241	100	726	246	89	1384	487	189
Bluefin tuna	0	0	0	1	*	*	1	*	*
Skipjack tuna	2	1	*	4	1	1	6	2	1
Total tunas	899	346	148	1609	514	185	2508	860	333
				Annual catch[2]					
Blue marlin	112	46	20	125	63	23	237	109	43
Striped marlin	477	211	97	629	334	121	1106	545	218
Swordfish	19	9	4	247	110	47	266	119	51
Black marlin	2	1	*	2	1	*	4	2	*
Spearfish & sailfish	25	11	5	28	15	6	53	26	11
Total billfishes	635	278	126	1031	523	197	1666	801	323

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 10.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1969.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	111	40	17	253	78	30	364	118	47
February	49	24	11	333	126	48	382	150	59
March	43	16	7	41	9	3	84	25	10
April	41	15	6	4	2	1	45	17	7
May	89	39	16	65	40	15	154	79	33
June	23	10	5	18	10	4	41	20	9
July	14	5	2	*	*	0	14	5	2
August	13	4	2	0	0	0	13	4	2
September	77	27	11	48	7	2	125	34	13
October	58	18	7	175	54	18	233	72	25
November	126	44	18	180	47	17	306	91	35
December	87	30	13	244	69	27	331	99	40
Total	731	272	117	1361	442	165	2092	714	282
				Annual catch[2]					
Albacore	22	7	3	512	90	33	534	97	36
Yellowfin tuna	184	71	32	199	82	31	383	153	63
Bigeye tuna	727	263	112	1181	409	157	1908	672	269
Bluefin tuna	0	0	0	5	1	*	5	1	*
Skipjack tuna	1	*	*	2	1	*	3	1	*
Total tunas	934	341	147	1899	583	221	2833	924	368
				Annual catch[2]					
Blue marlin	59	22	9	26	12	4	85	34	13
Striped marlin	124	49	21	144	68	25	268	117	46
Swordfish	18	7	3	143	42	16	161	49	19
Black marlin	1	*	*	1	*	*	2	*	*
Spearfish & sailfish	7	3	1	4	2	1	11	5	2
Total billfishes	209	81	34	318	124	46	527	205	80

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 11.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1970.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	76	22	7	234	71	26	310	93	33
February	135	41	15	100	15	4	235	56	19
March	53	19	9	38	9	3	91	28	12
April	30	7	2	10	4	1	40	11	3
May	110	49	21	299	148	48	409	197	69
June	128	52	21	231	141	52	359	193	73
July	73	32	15	70	41	15	143	73	30
August	47	21	11	8	3	1	55	24	12
September	15	4	2	1	*	0	16	4	2
October	80	32	15	179	90	33	259	122	48
November	77	26	10	384	173	64	461	199	74
December	156	74	34	616	298	114	772	372	148
Total	980	379	162	2170	993	361	3150	1372	523
				Annual catch[2]					
Albacore	42	16	7	416	110	40	458	126	47
Yellowfin tuna	511	200	85	720	384	140	1231	584	225
Bigeye tuna	664	228	90	1061	453	168	1725	681	258
Bluefin tuna	1	1	*	3	1	*	4	2	*
Skipjack tuna	2	1	*	4	2	1	6	3	1
Total tunas	1220	446	182	2204	950	349	3424	1396	531
				Annual catch[2]					
Blue marlin	117	50	22	329	177	63	446	227	85
Striped marlin	214	93	41	753	398	143	967	491	184
Swordfish	26	10	4	123	38	13	151	48	17
Black marlin	1	*	*	3	2	1	4	2	1
Spearfish & sailfish	23	9	4	52	29	10	75	38	14
Total billfishes	383	162	71	1260	644	230	1643	806	301

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 12.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1971.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	146	42	18	505	236	110	651	278	128
February	113	15	2	285	79	20	398	94	22
March	5	2	*	42	12	5	47	14	5
April	3	*	0	3	2	1	6	2	1
May	16	1	0	33	25	3	49	26	3
June	5	1	0	61	42	12	66	43	12
July	9	2	0	28	2	1	37	4	1
August	18	2	0	0	0	0	18	2	0
September	13	0	0	42	17	9	55	17	9
October	105	18	5	118	42	18	223	60	23
November	49	6	*	234	147	72	283	153	72
December	68	31	12	202	102	28	270	133	40
Total	550	120	37	1553	706	279	2103	826	316
				Annual catch[2]					
Albacore	39	8	4	398	104	29	437	112	33
Yellowfin tuna	271	48	14	467	236	91	738	284	105
Bigeye tuna	428	54	15	821	375	148	1249	429	163
Bluefin tuna	0	0	0	1	*	0	1	*	0
Skipjack tuna	1	*	*	2	1	*	3	1	*
Total tunas	739	110	33	1689	716	268	2428	826	301
				Annual catch[2]					
Blue marlin	33	6	2	81	46	17	114	52	19
Striped marlin	62	17	6	261	169	76	323	186	82
Swordfish	5	1	*	63	24	8	68	25	8
Black marlin	2	1	1	4	3	1	6	4	2
Spearfish & sailfish	4	1	*	8	4	1	12	5	1
Total billfishes	106	26	9	417	246	103	523	272	112

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 13.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1972.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	22	6	2	205	30	3	227	36	5
February	56	6	*	135	14	2	191	20	2
March	32	8	4	216	23	2	248	31	6
April	5	1	0	2	0	0	7	1	0
May	43	11	4	154	54	2	197	65	6
June	18	1	0	65	41	2	83	42	2
July	7	0	0	0	0	0	7	0	0
August	8	0	0	20	2	*	28	2	*
September	13	2	1	0	0	0	13	2	1
October	60	25	9	102	38	16	162	63	25
November	10	5	2	94	37	17	104	42	19
December	88	55	22	704	308	116	792	363	138
Total	362	120	44	1697	547	160	2059	667	204
				Annual catch[2]					
Albacore	44	28	12	478	80	15	522	108	27
Yellowfin tuna	118	51	19	260	106	15	378	157	34
Bigeye tuna	261	52	18	1284	445	164	1545	497	182
Bluefin tuna	0	0	0	2	*	0	2	*	0
Skipjack tuna	1	*	*	2	1	*	3	1	*
Total tunas	424	131	49	2026	632	194	2450	763	243
				Annual catch[2]					
Blue marlin	15	3	1	62	31	3	77	34	4
Striped marlin	23	9	3	173	79	12	196	88	15
Swordfish	12	3	*	192	36	6	204	39	6
Black marlin	1	*	0	2	2	1	3	2	1
Spearfish & sailfish	5	1	*	8	1	*	13	2	*
Total billfishes	56	16	4	437	149	22	493	165	26

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 14.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1973.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	47	16	8	297	129	58	344	145	66
February	58	7	2	47	16	11	105	23	13
March	45	*	0	58	10	3	103	10	3
April	13	0	0	11	5	1	24	5	1
May	83	1	0	62	8	*	145	9	*
June	42	3	0	39	5	*	81	8	*
July	7	7	5	3	2	1	10	9	6
August	3	0	0	2	1	*	5	1	*
September	1	0	0	5	*	0	6	*	0
October	45	19	11	67	27	12	112	46	23
November	63	14	1	138	55	23	201	69	24
December	185	25	2	234	63	22	419	88	24
Total	592	92	29	963	321	131	1555	413	160
				Annual catch[2]					
Albacore	115	18	3	348	117	48	463	135	51
Yellowfin tuna	181	34	12	133	34	8	314	68	20
Bigeye tuna	451	32	9	496	175	65	947	207	74
Bluefin tuna	0	0	0	2	*	0	2	*	0
Skipjack tuna	1	*	*	1	*	*	2	*	*
Total tunas	748	84	24	980	326	121	1728	410	145
				Annual catch[2]					
Blue marlin	15	3	1	18	4	1	33	7	2
Striped marlin	38	7	3	78	24	8	116	31	11
Swordfish	14	3	2	89	16	5	103	19	7
Black marlin	*	*	0	1	*	*	1	*	*
Spearfish & sailfish	13	1	*	10	2	*	23	3	*
Total billfishes	80	14	6	196	46	14	276	60	20

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 15.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1974.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	213	58	15	150	86	52	363	144	67
February	42	9	1	40	4	2	82	13	3
March	51	25	6	37	11	5	88	36	11
April	16	2	0	10	4	1	26	6	1
May	93	1	0	3	1	*	96	2	*
June	308	21	1	11	7	*	319	28	1
July	187	12	*	103	5	*	290	17	*
August	23	12	1	15	3	*	38	15	1
September	15	1	0	14	0	0	29	1	0
October	91	23	3	2	0	0	93	23	3
November	78	27	10	18	1	*	96	28	10
December	172	19	1	30	6	*	202	25	1
Total	1289	210	38	433	128	60	1722	338	98
				Annual catch[2]					
Albacore	173	35	4	281	94	46	454	129	50
Yellowfin tuna	332	63	12	119	36	26	451	99	38
Bigeye tuna	715	92	14	95	30	15	810	122	29
Bluefin tuna	0	0	0	2	*	*	2	*	*
Skipjack tuna	2	*	*	1	*	*	3	*	*
Total tunas	1222	190	30	498	160	87	1720	350	117
				Annual catch[2]					
Blue marlin	59	9	2	24	3	*	83	12	2
Striped marlin	58	13	3	20	5	1	78	18	4
Swordfish	22	3	*	45	10	4	67	13	4
Black marlin	2	*	*	1	*	*	3	*	*
Spearfish & sailfish	38	7	1	7	1	*	45	8	1
Total billfishes	179	32	6	97	19	5	276	51	11

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 16.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1975.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	92	12	*	69	42	23	161	54	23
February	66	5	*	52	33	11	118	38	11
March	8	3	*	33	28	11	41	31	11
April	2	0	0	0	0	0	2	0	0
May	39	0	0	0	0	0	39	0	0
June	19	0	0	25	3	1	44	3	1
July	13	0	0	18	1	0	31	1	0
August	10	3	0	4	1	0	14	4	0
September	3	0	0	0	0	0	3	0	0
October	7	6	5	152	141	111	159	147	116
November	13	13	11	214	191	111	227	204	122
December	70	4	*	261	140	74	331	144	74
Total	342	46	16	828	580	342	1170	626	358
				Annual catch[2]					
Albacore	79	8	1	170	65	34	249	73	35
Yellowfin tuna	81	7	1	171	115	69	252	122	70
Bigeye tuna	145	24	15	512	392	242	657	416	257
Bluefin tuna	0	0	0	2	2	1	2	2	1
Skipjack tuna	1	*	*	1	*	*	2	*	*
Total tunas	306	39	17	856	574	346	1162	613	363
				Annual catch[2]					
Blue marlin	6	1	*	14	6	4	20	7	4
Striped marlin	23	3	1	70	46	18	93	49	19
Swordfish	7	*	0	27	9	4	34	9	4
Black marlin	*	*	*	1	1	*	1	1	*
Spearfish & sailfish	7	*	*	7	4	2	14	4	2
Total billfishes	43	4	1	119	66	28	162	70	29

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 17.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1976.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	14	6	4	400	167	66	414	173	70
February	119	78	44	427	213	81	546	291	125
March	67	30	14	225	126	50	292	156	64
April	91	35	16	8	5	2	99	40	18
May	159	59	27	*	*	0	163	59	27
June	203	75	33	7	3	1	210	78	34
July	7	3	1	1	*	*	8	3	1
August	1	*	*	3	1	*	4	1	*
September	23	11	5	139	78	32	162	89	37
October	60	29	14	191	94	36	251	123	50
November	17	11	5	108	49	18	125	60	23
December	62	39	22	343	160	64	405	199	86
Total	823	376	185	1856	896	350	2679	1272	535
				Annual catch[2]					
Albacore	95	55	31	912	357	140	1007	412	171
Yellowfin tuna	227	124	68	330	180	70	557	304	138
Bigeye tuna	673	279	132	1155	563	221	1828	842	353
Bluefin tuna	0	0	0	1	*	*	1	*	*
Skipjack tuna	1	*	*	1	1	*	2	1	*
Total tunas	996	458	231	2399	1101	431	3395	1559	662
				Annual catch[2]					
Blue marlin	23	10	5	22	12	5	45	22	10
Striped marlin	32	16	8	136	73	29	168	89	37
Swordfish	47	18	8	220	109	44	267	127	52
Black marlin	1	1	*	1	*	*	2	1	*
Spearfish & sailfish	7	3	2	8	4	2	15	7	4
Total billfishes	110	48	23	387	198	80	497	246	103

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 18.--Estimated catch and effort by Japanese longliners within 200, 100, and 50 miles of the Hawaiian Islands, 1977.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	100	58	32	406	209	80	506	267	112
February	159	100	58	113	53	18	272	153	76
March	20	13	8	33	18	7	53	31	15
April	14	5	2	0	0	0	14	5	2
May	104	36	15	6	*	0	110	36	15
June	141	48	20	21	5	2	162	53	22
July	21	9	4	43	25	9	64	34	13
August	74	26	11	3	1	*	77	27	11
September	85	29	12	50	24	9	135	53	21
October	62	22	10	28	5	2	90	27	12
November	19	6	3	90	33	12	109	39	15
December	43	19	8	664	312	114	707	331	122
Total	842	371	183	1457	685	253	2299	1056	436
				Annual catch[2]					
Albacore	47	20	11	446	162	61	493	182	72
Yellowfin tuna	206	120	68	304	156	57	510	276	125
Bigeye tuna	806	317	147	1510	709	262	2316	1026	409
Bluefin tuna	0	0	0	1	*	*	1	*	*
Skipjack tuna	1	*	*	1	*	*	2	*	*
Total tunas	1060	457	226	2262	1027	380	3322	1484	606
				Annual catch[2]					
Blue marlin	37	15	7	26	13	5	63	28	12
Striped marlin	31	15	8	113	61	23	144	76	31
Swordfish	25	9	4	57	27	11	82	36	15
Black marlin	1	1	*	2	1	*	3	2	*
Spearfish & sailfish	8	3	1	5	2	1	13	5	2
Total billfishes	102	43	20	203	104	40	305	147	60

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 19.--Estimated catch and effort by longliners of Taiwan within 200, 100, and 50 miles of the Hawaiian Islands, 1972.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	33	16	6	33	16	6
July	0	0	0	20	7	3	20	7	3
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	0	0	0	53	23	9	53	23	9
				Annual catch[2]					
Albacore	0	0	0	99	39	14	99	39	14
Yellowfin tuna	0	0	0	17	7	3	17	7	3
Bigeye tuna	0	0	0	3	1	*	3	1	*
Bluefin tuna	0	0	0	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0	0	0	0
Total tunas	0	0	0	119	47	17	119	47	17
				Annual catch[2]					
Blue marlin	0	0	0	0	0	0	0	0	0
Striped marlin	0	0	0	3	1	*	3	1	*
Swordfish	0	0	0	0	0	0	0	0	0
Black marlin	0	0	0	0	0	0	0	0	0
Spearfish & sailfish	0	0	0	0	0	0	0	0	0
Total billfishes	0	0	0	3	1	*	3	1	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 20.--Estimated catch and effort by longliners of Taiwan within 200, 100, and 50 miles of the Hawaiian Islands, 1977.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	5	2	1	47	19	7	52	21	8
February	4	2	1	4	*	0	8	2	1
March	1	*	*	0	0	0	1	*	*
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	10	4	2	51	19	7	61	23	9
				Annual catch[2]					
Albacore	7	1	1	34	7	2	41	8	3
Yellowfin tuna	2	1	1	4	2	1	6	3	2
Bigeye tuna	1	1	*	4	2	1	5	3	1
Bluefin tuna	0	0	0	0	0	0	0	0	0
Skipjack tuna	0	0	0	*	*	0	*	*	0
Total tunas	10	3	2	42	11	4	52	14	6
				Annual catch[2]					
Blue marlin	*	0	0	1	*	*	1	*	*
Striped marlin	*	0	0	1	*	*	1	*	*
Swordfish	*	0	0	*	0	0	*	0	0
Black marlin	0	0	0	0	0	0	0	0	0
Spearfish & sailfish	0	0	0	0	0	0	0	0	0
Total billfishes	*	0	0	2	*	*	2	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 21.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1965.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	2	13	19	155	21	168
February	3	17	11	87	14	104
March	5	32	17	122	22	154
April	1	4	3	27	4	31
May	*	1	6	49	6	50
June	1	4	6	41	7	45
July	1	8	1	5	2	13
August	1	7	1	4	2	11
September	1	9	*	1	1	10
October	17	103	10	37	27	140
November	4	27	4	20	8	47
December	8	50	10	55	18	105
Total	44	275	88	603	132	878
	Annual catch[2]					
Albacore	8	48	8	55	16	103
Yellowfin tuna	26	160	20	95	46	255
Bigeye tuna	6	41	15	96	21	137
Bluefin tuna	*	*	*	2	*	2
Skipjack tuna	*	*	*	*	*	*
Total tunas	40	249	43	248	83	497
	Annual catch[2]					
Blue marlin	6	36	8	40	14	76
Striped marlin	*	1	4	36	4	37
Swordfish	*	1	3	24	3	25
Black marlin	*	1	*	1	*	2
Spearfish & sailfish	*	2	1	7	1	9
Total billfishes	6	41	16	108	22	149

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 22.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1966.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	1	6	4	33	5	39
February	*	2	4	30	4	32
March	3	22	5	17	8	39
April	6	36	6	37	12	73
May	3	22	6	43	9	65
June	0	1	4	42	4	43
July	*	3	3	18	3	21
August	3	18	5	24	8	42
September	4	26	5	25	9	51
October	9	55	5	19	14	74
November	3	20	1	5	4	25
December	2	15	3	16	5	31
Total	34	226	51	309	85	535
	Annual catch[2]					
Albacore	3	17	4	28	7	45
Yellowfin tuna	20	126	19	106	39	232
Bigeye tuna	5	31	6	34	11	65
Bluefin tuna	*	*	*	1	*	1
Skipjack tuna	*	*	*	*	*	*
Total tunas	28	174	29	169	57	343
	Annual catch[2]					
Blue marlin	4	29	6	39	10	68
Striped marlin	*	*	1	9	1	9
Swordfish	*	*	2	19	2	19
Black marlin	*	1	*	1	*	2
Spearfish & sailfish	*	3	1	5	1	8
Total billfishes	4	33	10	73	14	106

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 23.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1967.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	2	15	11	86	13	101
February	7	44	13	80	20	124
March	3	19	5	31	8	50
April	4	26	10	46	14	72
May	5	28	7	42	12	70
June	*	3	8	65	8	68
July	*	3	1	4	1	7
August	1	7	2	9	3	16
September	*	2	*	1	*	3
October	*	3	*	*	*	3
November	0	0	*	2	*	2
December	3	16	12	102	15	118
Total	25	166	69	468	94	634
	Annual catch[2]					
Albacore	*	3	9	79	9	82
Yellowfin tuna	7	42	9	47	16	89
Bigeye tuna	7	44	13	81	20	125
Bluefin tuna	0	0	*	*	*	*
Skipjack tuna	*	*	*	*	*	*
Total tunas	14	89	31	207	45	296
	Annual catch[2]					
Blue marlin	3	17	5	27	8	44
Striped marlin	*	1	2	17	2	18
Swordfish	*	1	4	26	4	27
Black marlin	*	1	*	1	*	2
Spearfish & sailfish	*	2	1	5	1	7
Total billfishes	3	22	12	76	15	98

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 24.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1968.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	*	3	8	64	8	67
February	6	37	11	66	17	103
March	12	74	14	84	26	158
April	3	20	9	67	12	87
May	2	12	3	14	5	26
June	2	14	4	33	6	47
July	1	10	6	51	7	61
August	2	15	1	4	3	19
September	2	10	1	6	3	16
October	*	3	1	3	1	6
November	1	6	1	10	2	16
December	2	10	10	83	12	93
Total	33	214	69	485	102	699
	Annual catch[2]					
Albacore	2	12	10	95	12	107
Yellowfin tuna	17	104	11	52	28	156
Bigeye tuna	8	48	9	52	17	100
Bluefin tuna	*	*	*	*	*	*
Skipjack tuna	*	1	*	*	*	1
Total tunas	27	165	30	199	57	364
	Annual catch[2]					
Blue marlin	3	20	4	25	7	45
Striped marlin	*	1	2	16	2	17
Swordfish	*	1	4	32	4	33
Black marlin	*	1	*	*	*	1
Spearfish & sailfish	*	3	1	3	1	6
Total billfishes	3	26	11	76	14	102

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 25.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1969.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	1	6	22	165	23	171
February	5	31	11	56	16	87
March	5	32	7	39	12	71
April	1	5	4	32	5	37
May	*	2	1	7	1	9
June	0	0	2	16	2	16
July	1	6	1	11	2	17
August	*	2	3	21	3	23
September	0	0	0	0	0	0
October	1	5	3	11	4	16
November	1	6	3	21	4	27
December	4	24	6	33	10	57
Total	19	119	63	412	82	531
	Annual catch[2]					
Albacore	2	10	9	79	11	89
Yellowfin tuna	6	42	14	71	20	113
Bigeye tuna	5	34	14	72	19	106
Bluefin tuna	0	0	*	*	*	*
Skipjack tuna	*	*	*	*	*	*
Total tunas	13	86	37	222	50	308
	Annual catch[2]					
Blue marlin	1	7	3	17	4	24
Striped marlin	*	1	2	13	2	14
Swordfish	*	1	2	17	2	18
Black marlin	*	1	*	1	*	2
Spearfish & sailfish	*	*	*	1	*	1
Total billfishes	1	10	7	49	8	59

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 26.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1970.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	4	24	8	54	12	78
February	4	24	22	167	26	191
March	2	15	42	226	44	241
April	1	7	8	64	9	71
May	3	16	7	66	10	82
June	1	7	7	66	8	73
July	1	3	1	5	2	8
August	1	7	5	27	6	34
September	2	12	4	23	6	35
October	2	13	8	45	10	58
November	1	4	9	39	10	43
December	0	1	25	88	25	89
Total	22	133	146	870	168	1003
			Annual catch[2]			
Albacore	1	7	17	92	18	99
Yellowfin tuna	10	68	44	220	54	288
Bigeye tuna	4	26	14	85	18	111
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	*	*	1	4	1	4
Total tunas	15	101	76	401	91	502
			Annual catch[2]			
Blue marlin	2	13	11	63	13	76
Striped marlin	*	1	9	71	9	72
Swordfish	*	1	5	37	5	38
Black marlin	*	*	*	3	*	3
Spearfish & sailfish	*	1	3	16	3	17
Total billfishes	2	16	28	190	30	206

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 27.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1971.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	1	2	17	2	18
February	0	1	13	123	13	124
March	0	0	18	176	18	176
April	0	0	4	59	4	59
May	0	0	*	5	*	5
June	0	0	1	21	1	21
July	0	0	2	12	2	12
August	0	0	1	19	1	19
September	0	0	47	72	47	72
October	0	0	113	136	113	136
November	13	17	54	99	67	116
December	0	0	64	282	64	282
Total	13	19	319	1021	332	1040
	Annual catch[2]					
Albacore	0	*	71	178	71	178
Yellowfin tuna	6	8	95	216	101	224
Bigeye tuna	1	1	20	97	21	98
Bluefin tuna	0	0	*	*	*	*
Skipjack tuna	*	*	*	*	*	*
Total tunas	7	9	186	491	193	500
	Annual catch[2]					
Blue marlin	2	2	20	54	22	56
Striped marlin	*	*	6	48	6	48
Swordfish	*	*	4	28	4	28
Black marlin	0	0	2	5	2	5
Spearfish & sailfish	0	0	2	17	2	17
Total billfishes	2	2	34	152	36	154

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 28.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1972.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	0	59	151	59	151
February	0	1	23	65	23	66
March	0	1	4	37	4	38
April	0	0	5	42	5	42
May	0	15	2	14	2	29
June	0	2	16	37	16	39
July	0	0	2	12	2	12
August	0	0	25	29	25	29
September	0	1	30	39	30	40
October	0	0	25	54	25	54
November	0	0	19	44	19	44
December	0	0	30	69	30	69
Total	0	20	240	593	240	613
	Annual catch[2]					
Albacore	0	*	82	168	82	168
Yellowfin tuna	0	5	70	111	70	116
Bigeye tuna	0	6	14	48	14	54
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	1	1	1	1
Total tunas	0	11	167	328	167	339
	Annual catch[2]					
Blue marlin	0	2	8	22	8	24
Striped marlin	0	*	3	20	3	20
Swordfish	0	*	4	20	4	20
Black marlin	0	0	1	2	1	2
Spearfish & sailfish	0	0	5	9	5	9
Total billfishes	0	2	21	73	21	75

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 29.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1973.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	0	16	23	16	23
February	0	8	3	26	3	34
March	*	5	4	46	4	51
April	*	9	1	5	1	14
May	0	3	*	2	*	5
June	4	10	3	16	7	26
July	0	12	*	2	*	14
August	0	0	1	11	1	11
September	0	0	1	6	1	6
October	*	3	0	1	*	4
November	0	5	8	34	8	39
December	0	0	6	61	6	61
Total	4	55	43	233	47	288
	Annual catch[2]					
Albacore	1	5	22	100	23	105
Yellowfin tuna	1	22	3	21	4	43
Bigeye tuna	1	17	3	24	4	41
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	*	*	*	*
Total tunas	3	44	28	145	31	189
	Annual catch[2]					
Blue marlin	*	7	1	7	1	14
Striped marlin	*	1	1	11	1	12
Swordfish	*	1	1	9	1	10
Black marlin	0	0	*	*	*	*
Spearfish & sailfish	*	*	*	*	*	*
Total billfishes	*	9	3	27	3	36

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 30.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1974.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	*	4	1	5	1	9
February	0	23	5	51	5	74
March	7	97	6	62	13	159
April	11	21	18	103	29	124
May	*	44	7	59	7	103
June	0	13	2	31	2	44
July	0	6	0	0	0	6
August	0	0	*	1	*	1
September	*	23	0	0	*	23
October	0	42	0	7	0	49
November	0	0	0	15	0	15
December	0	*	*	3	*	3
Total	18	273	39	337	57	610
	Annual catch[2]					
Albacore	1	70	1	20	2	90
Yellowfin tuna	13	111	4	28	17	139
Bigeye tuna	6	53	5	23	11	76
Bluefin tuna	0	0	*	*	*	*
Skipjack tuna	0	*	*	*	*	*
Total tunas	20	234	10	71	30	305
	Annual catch[2]					
Blue marlin	1	27	2	19	3	46
Striped marlin	*	3	6	63	6	66
Swordfish	*	2	4	29	4	31
Black marlin	0	*	*	*	*	*
Spearfish & sailfish	*	4	*	2	*	6
Total billfishes	1	36	12	113	13	149

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 31.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1975.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	23	5	42	5	65
February	0	17	7	61	7	78
March	2	25	12	99	14	124
April	6	27	17	36	23	63
May	0	0	2	21	2	21
June	0	0	*	1	*	1
July	2	20	1	4	3	24
August	*	2	3	3	3	5
September	*	23	5	6	5	29
October	10	133	3	41	13	174
November	0	2	2	16	2	18
December	0	6	1	12	1	18
Total	20	278	58	342	78	620
	Annual catch[2]					
Albacore	5	58	14	90	19	148
Yellowfin tuna	7	100	7	48	14	148
Bigeye tuna	2	44	3	30	5	74
Bluefin tuna	0	0	*	1	*	1
Skipjack tuna	*	*	*	*	*	*
Total tunas	14	202	24	169	38	371
	Annual catch[2]					
Blue marlin	3	36	3	14	6	50
Striped marlin	*	*	3	21	3	21
Swordfish	*	1	5	36	5	37
Black marlin	0	*	*	*	*	*
Spearfish & sailfish	0	*	*	1	*	1
Total billfishes	3	37	11	72	14	109

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 32.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1976.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	10	60	13	88	23	148
February	6	36	9	57	15	93
March	2	13	6	44	8	57
April	5	30	5	21	10	51
May	1	7	1	5	2	12
June	1	7	1	7	2	14
July	6	39	3	13	9	52
August	5	30	5	27	10	57
September	5	30	4	25	9	55
October	11	65	5	37	16	102
November	31	192	18	127	49	319
December	37	226	13	49	50	275
Total	120	735	83	500	203	1235
	Annual catch[2]					
Albacore	14	90	13	91	27	181
Yellowfin tuna	93	577	44	190	137	767
Bigeye tuna	41	252	21	95	62	347
Bluefin tuna	0	*	*	*	*	*
Skipjack tuna	*	3	*	1	*	4
Total tunas	148	922	78	377	226	1299
	Annual catch[2]					
Blue marlin	9	58	6	32	15	90
Striped marlin	*	2	1	8	1	10
Swordfish	2	10	3	20	5	30
Black marlin	*	1	*	1	*	2
Spearfish & sailfish	*	2	*	2	*	4
Total billfishes	11	73	10	63	21	136

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 33.--Estimated catch and effort by Japanese longliners around Guam and the Northern Mariana Islands, 1977.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	17	106	14	77	31	183
February	5	34	8	48	13	82
March	11	69	12	70	23	139
April	8	48	5	20	13	68
May	29	183	20	83	49	266
June	26	168	34	137	60	305
July	20	130	25	108	45	238
August	8	52	10	45	18	97
September	13	80	15	64	28	144
October	22	136	17	74	39	210
November	24	152	21	94	45	246
December	7	41	9	57	16	98
Total	190	1199	190	877	380	2076
	Annual catch[2]					
Albacore	7	49	12	109	19	158
Yellowfin tuna	217	1368	208	861	425	2229
Bigeye tuna	90	572	94	406	184	978
Bluefin tuna	*	*	*	1	*	1
Skipjack tuna	*	*	*	*	*	*
Total tunas	314	1989	314	1377	628	3366
	Annual catch[2]					
Blue marlin	14	87	15	63	29	150
Striped marlin	*	1	*	2	*	3
Swordfish	1	9	2	13	3	22
Black marlin	1	5	1	4	2	9
Spearfish & sailfish	*	2	*	1	*	3
Total billfishes	16	104	18	83	34	187

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 34.--Estimated catch and effort by longliners of Taiwan around Guam and the Northern Mariana Islands, 1967.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	2	12	2	10	4	22
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	2	12	2	10	4	22
	Annual catch[2]					
Albacore	0	0	0	0	0	0
Yellowfin tuna	*	2	*	2	*	4
Bigeye tuna	*	1	*	1	*	2
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	*	3	*	3	*	6
	Annual catch[2]					
Blue marlin	*	1	*	1	*	2
Striped marlin	*	*	*	*	*	*
Swordfish	0	0	0	0	0	0
Black marlin	*	*	*	*	*	*
Spearfish & sailfish	*	*	*	*	*	*
Total billfishes	*	1	*	1	*	2

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 35.--Estimated catch and effort by foreign longliners based at American Samoa, 1965.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	20	31	42	93	867	159	275	1301	887	190	317	1394	5	*	1	6
February	12	2	1	15	702	158	329	1189	714	160	330	1204	0	0	0	0
March	6	12	3	21	584	117	355	1056	590	129	358	1077	0	0	1	1
April	0	*	0	*	802	272	379	1453	802	272	379	1453	0	0	0	0
May	0	3	3	6	467	216	337	1020	467	219	340	1026	0	0	1	1
June	0	2	12	14	654	218	327	1199	654	220	339	1213	0	1	7	8
July	0	3	5	8	512	169	338	1019	512	172	343	1027	0	0	3	3
August	0	12	6	18	625	137	331	1093	625	149	337	1111	0	3	3	6
September	1	7	21	29	588	123	371	1082	589	130	392	1111	0	1	6	7
October	5	24	8	37	569	187	418	1174	574	211	426	1211	0	1	3	4
November	18	47	49	114	793	142	260	1195	811	189	309	1309	*	8	14	22
December	86	42	66	194	1001	139	443	1583	1087	181	509	1777	4	26	14	44
Total	148	185	216	549	8164	2037	4163	14364	8312	2222	4379	14913	9	40	53	102
								Annual catch[2]								
Albacore	124	143	171	438	9289	1559	4173	15021	9413	1702	4344	15459	6	30	42	78
Yellowfin tuna	21	27	40	88	2694	761	1604	5059	2715	788	1644	5147	2	5	11	18
Bigeye tuna	5	15	26	46	1448	423	1485	3356	1453	438	1511	3402	*	2	5	7
Bluefin tuna	0	*	*	*	3	3	3	9	3	3	3	9	0	*	0	*
Skipjack tuna	*	*	*	*	17	3	9	29	17	3	9	29	*	*	*	*
Total tunas	150	185	237	572	13451	2749	7274	23474	13601	2934	7511	24046	9	37	58	103
								Annual catch[2]								
Blue marlin	1	5	7	13	35	36	125	196	36	41	132	209	*	2	1	3
Striped marlin	*	*	3	3	13	3	56	72	13	3	59	75	*	*	*	*
Swordfish	*	*	3	3	5	3	25	33	5	3	28	36	*	*	*	*
Black marlin	*	3	5	8	2	36	31	69	2	39	36	77	0	*	*	*
Spearfish & sailfish	*	*	*	*	7	3	11	21	7	3	11	21	*	*	*	*
Total billfishes	1	8	18	27	62	81	248	391	63	89	266	418	*	2	1	3
								Annual catch[2]								
Wahoo	5	1	4	10	194	16	56	266	199	17	60	276	*	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 36.--Estimated catch and effort by foreign longliners based at American Samoa, 1966.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	20	35	32	87	668	207	367	1242	688	242	399	1329	8	5	4	17
February	11	5	8	24	538	372	456	1366	549	377	464	1390	3	0	4	7
March	18	37	23	78	473	498	495	1466	491	535	518	1544	9	2	0	11
April	1	5	6	12	266	548	405	1219	267	553	411	1231	0	0	1	1
May	*	16	3	19	401	713	818	1932	401	729	821	1951	*	2	0	2
June	0	45	0	45	572	554	911	2037	572	599	911	2082	0	1	0	1
July	1	53	11	65	843	662	806	2311	844	715	817	2376	0	11	0	11
August	0	35	2	37	888	651	728	2267	888	686	730	2304	0	14	0	14
September	7	21	1	29	696	647	667	2010	703	668	668	2039	3	7	0	10
October	3	99	26	128	791	862	878	2531	794	961	904	2659	0	5	8	13
November	27	165	37	229	599	725	961	2285	626	890	998	2514	1	6	7	14
December	4	134	10	148	522	1021	839	2382	526	1155	849	2530	2	8	2	12
Total	92	650	159	901	7257	7460	8331	23048	7349	8110	8490	23949	26	61	26	113
								Annual catch[2]								
Albacore	52	425	105	582	8848	7047	9012	24907	8900	7472	9117	25489	11	34	15	60
Yellowfin tuna	19	88	25	132	2749	2343	2297	7389	2768	2431	2322	7521	7	7	4	18
Bigeye tuna	10	54	18	82	1544	1011	2613	5168	1554	1065	2631	5250	3	4	1	8
Bluefin tuna	*	1	*	1	14	3	9	26	14	4	9	27	*	*	0	*
Skipjack tuna	*	1	*	1	20	16	29	65	20	17	29	66	*	*	*	*
Total tunas	81	569	148	798	13175	10420	13960	37555	13256	10989	14108	38353	21	45	20	86
								Annual catch[2]								
Blue marlin	*	38	3	41	*	408	224	632	*	446	227	673	*	2	1	3
Striped marlin	*	3	3	6	*	104	73	177	*	107	76	183	*	*	1	1
Swordfish	*	5	2	7	*	31	39	70	*	36	41	77	*	1	*	1
Black marlin	*	2	2	4	*	60	92	152	*	62	94	156	*	*	*	*
Spearfish & sailfish	*	1	1	2	*	35	28	63	*	36	29	65	*	*	*	*
Total billfishes	*	49	11	60	*	638	456	1094	*	687	467	1154	*	3	2	5
								Annual catch[2]								
Wahoo	2	5	2	9	121	76	168	365	123	81	170	374	1	*	1	2

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 37.--Estimated catch and effort by foreign longliners based at American Samoa, 1967.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	35	1	36	395	702	843	1940	395	737	844	1976	0	4	0	4
February	0	20	16	36	371	852	858	2081	371	872	874	2117	0	4	2	6
March	0	35	4	39	538	838	995	2371	538	873	999	2410	0	7	0	7
April	1	30	5	36	620	791	948	2359	621	821	953	2395	*	4	*	4
May	0	19	8	27	689	1037	894	2620	689	1056	902	2647	0	2	2	4
June	0	8	0	8	795	934	907	2636	795	942	907	2644	0	3	0	3
July	0	3	1	4	727	995	944	2666	727	998	945	2670	0	*	0	*
August	0	9	4	13	980	1049	1009	3038	980	1058	1013	3051	0	*	0	*
September	0	13	10	23	726	965	775	2466	726	978	785	2489	0	1	5	6
October	0	40	1	41	626	1241	922	2789	626	1281	923	2830	0	9	0	9
November	10	59	2	71	447	1014	916	2377	457	1073	918	2448	0	7	0	7
December	0	41	1	42	283	817	606	1706	283	858	607	1748	0	8	*	8
Total	11	312	53	376	7197	11235	10617	29049	7208	11547	10670	29425	*	49	9	58
								Annual catch[2]								
Albacore	8	150	19	177	7469	10869	9680	28018	7477	11019	9699	28195	*	24	3	27
Yellowfin tuna	1	41	8	50	1292	2389	2373	6054	1293	2430	2381	6104	*	6	3	9
Bigeye tuna	*	21	3	24	1153	2092	3128	6373	1153	2113	3131	6397	0	*	*	*
Bluefin tuna	0	*	*	*	8	11	9	28	8	11	9	28	0	*	0	*
Skipjack tuna	*	1	*	1	28	29	33	90	28	30	33	91	0	*	*	*
Total tunas	9	213	30	252	9950	15390	15223	40563	9959	15603	15253	40815	*	34	6	40
								Annual catch[2]								
Blue marlin	*	18	1	19	1	412	151	564	1	430	152	583	*	3	*	3
Striped marlin	*	*	*	*	1	134	55	190	1	134	55	190	0	*	*	*
Swordfish	0	*	*	*	*	37	16	53	*	37	16	53	0	*	0	*
Black marlin	*	2	1	3	*	68	57	125	*	70	58	128	0	*	*	*
Spearfish & sailfish	0	1	*	1	*	49	41	90	*	50	41	91	0	*	*	*
Total billfishes	*	21	2	23	2	700	320	1022	2	721	322	1045	*	3	*	3
								Annual catch[2]								
Wahoo	*	3	*	3	29	135	252	416	29	138	252	419	0	0	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 38.--Estimated catch and effort by foreign longliners based at American Samoa, 1968.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	1	50	0	51	448	993	685	2126	449	1043	685	2177	0	6	0	6
February	1	42	1	44	293	984	746	2023	294	1026	747	2067	0	2	0	2
March	*	48	9	57	396	1146	805	2347	396	1194	814	2404	0	2	0	2
April	*	45	2	47	403	1058	885	2346	403	1103	887	2393	0	6	0	6
May	0	39	1	40	490	1291	946	2727	490	1330	947	2767	0	2	1	3
June	0	33	3	36	383	1003	1132	2518	383	1036	1135	2554	0	7	1	8
July	0	3	2	5	359	1030	985	2374	359	1033	987	2379	0	0	0	0
August	0	22	4	26	372	937	820	2129	372	959	824	2155	0	2	2	4
September	0	21	1	22	282	566	772	1620	282	587	773	1642	0	7	0	7
October	0	19	13	32	186	575	757	1518	186	594	770	1550	0	9	*	9
November	2	4	29	35	170	474	840	1484	172	478	869	1519	1	0	24	25
December	1	14	23	38	165	371	704	1240	166	385	727	1278	0	4	10	14
Total	5	340	88	433	3947	10428	10077	24452	3952	10768	10165	24885	1	47	38	86
								Annual catch[2]								
Albacore	3	153	39	195	3153	7938	6438	17529	3156	8091	6477	17724	*	19	20	39
Yellowfin tuna	2	58	15	75	1208	3667	3488	8363	1210	3725	3503	8438	*	5	7	12
Bigeye tuna	*	15	3	18	319	1401	1474	3194	319	1416	1477	3212	*	1	1	2
Bluefin tuna	0	*	1	1	5	14	12	31	5	14	13	32	0	*	*	*
Skipjack tuna	*	*	*	*	5	13	31	49	5	13	31	49	0	*	*	*
Total tunas	5	226	58	289	4690	13033	11443	29166	4695	13259	11501	29455	*	25	28	53
								Annual catch[2]								
Blue marlin	*	49	1	50	5	1026	45	1076	5	1075	46	1126	*	4	*	4
Striped marlin	*	1	*	1	4	230	20	254	4	231	20	255	0	*	*	*
Swordfish	*	2	*	2	1	87	10	98	1	89	10	100	0	*	*	*
Black marlin	0	9	*	9	*	168	26	194	*	177	26	203	0	1	*	1
Spearfish & sailfish	*	3	*	3	1	76	29	106	1	79	29	109	*	*	*	*
Total billfishes	*	64	1	65	11	1587	130	1728	11	1651	131	1793	*	5	*	5
								Annual catch[2]								
Wahoo	*	5	*	5	6	80	147	233	6	85	147	238	*	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 39.--Estimated catch and effort by foreign longliners based at American Samoa, 1969.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	1	30	50	81	64	393	765	1222	65	423	815	1303	0	5	27	32
February	0	32	11	43	95	413	954	1462	95	445	965	1505	0	8	1	9
March	0	28	12	40	181	579	934	1694	181	607	946	1734	0	8	8	16
April	2	8	1	11	181	532	1012	1725	183	540	1013	1736	0	0	0	0
May	0	*	0	*	168	706	1064	1938	168	706	1064	1938	0	0	0	0
June	0	3	2	5	224	546	1191	1961	224	549	1193	1966	0	0	*	*
July	0	6	1	7	233	645	1328	2206	233	651	1329	2213	0	0	0	0
August	0	3	0	3	223	699	1214	2136	223	702	1214	2139	0	*	0	*
September	0	14	10	24	151	716	1134	2001	151	730	1144	2025	0	1	2	3
October	0	69	68	137	146	732	1381	2259	146	801	1449	2396	0	2	5	7
November	0	267	183	450	105	801	1172	2078	105	1068	1355	2528	0	9	1	10
December	0	163	47	210	45	725	1305	2075	45	888	1352	2285	0	9	3	12
Total	3	623	385	1011	1816	7487	13454	22757	1819	8110	13839	23768	0	42	47	89
								Annual catch[2]								
Albacore	1	501	249	751	1570	6395	10016	17981	1571	6896	10265	18732	0	28	16	44
Yellowfin tuna	1	103	85	189	746	2789	5636	9171	747	2892	5721	9360	0	7	17	24
Bigeye tuna	*	44	15	59	93	1467	2117	3677	93	1511	2132	3736	0	4	2	6
Bluefin tuna	0	1	2	3	4	19	11	34	4	20	13	37	0	*	1	1
Skipjack tuna	0	1	1	2	7	13	46	66	7	14	47	68	0	*	*	*
Total tunas	2	650	352	1004	2420	10683	17826	30929	2422	11333	18178	31933	0	39	36	75
								Annual catch[2]								
Blue marlin	*	184	7	191	53	1461	398	1912	53	1645	405	2103	0	15	1	16
Striped marlin	0	7	9	16	40	218	152	410	40	225	161	426	0	*	2	2
Swordfish	0	1	4	5	17	71	75	163	17	72	79	168	0	*	1	1
Black marlin	0	14	3	17	3	192	139	334	3	206	142	351	0	*	*	*
Spearfish & sailfish	0	11	1	12	8	306	134	448	8	317	135	460	0	1	*	1
Total billfishes	*	217	24	241	121	2248	898	3267	121	2465	922	3508	0	16	4	20
								Annual catch[2]								
Wahoo	*	*	4	4	6	27	152	185	6	27	156	189	0	0	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 40.--Estimated catch and effort by foreign longliners based at American Samoa, 1970.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
							Monthly nominal effort[1]									
January	0	38	11	49	82	1095	1193	2370	82	1133	1204	2419	0	3	3	6
February	0	23	1	24	38	926	1280	2244	38	949	1281	2268	0	0	0	0
March	0	8	10	18	112	1135	1216	2463	112	1143	1226	2481	0	0	0	0
April	0	103	41	144	127	1057	1043	2227	127	1160	1084	2371	0	5	0	5
May	0	5	2	7	99	1123	1212	2434	99	1128	1214	2441	0	*	1	1
June	0	48	9	57	131	1181	1012	2324	131	1229	1021	2381	0	*	0	*
July	0	7	2	9	124	1010	1083	2217	124	1017	1085	2226	0	*	0	*
August	0	10	0	10	81	851	1121	2053	81	861	1121	2063	0	*	0	*
September	0	55	1	56	80	754	891	1735	80	819	892	1791	0	13	0	13
October	0	52	15	67	46	1100	998	2144	46	1152	1013	2211	0	15	0	15
November	0	166	91	257	32	1281	1082	2395	32	1447	1173	2652	0	23	1	24
December	0	164	170	334	32	953	1013	1998	32	1117	1183	2332	0	10	2	12
Total	0	679	353	1032	984	12476	13144	26604	984	13155	13497	27636	0	69	7	76
							Annual catch[2]									
Albacore	0	433	173	606	952	10548	11770	23270	952	10981	11943	23876	0	33	2	35
Yellowfin tuna	0	138	45	183	260	4241	4168	8669	260	4379	4213	8852	0	9	1	10
Bigeye tuna	0	51	10	61	7	1859	1524	3390	7	1910	1534	3451	0	4	*	4
Bluefin tuna	0	3	*	3	*	24	14	38	*	27	14	41	0	*	*	*
Skipjack tuna	0	2	2	4	7	57	108	172	7	59	110	176	0	*	*	*
Total tunas	0	627	230	857	1226	16729	17584	35539	1226	17356	17814	36396	0	46	3	49
							Annual catch[2]									
Blue marlin	0	40	17	57	86	836	594	1516	86	876	611	1573	0	3	*	3
Striped marlin	0	6	5	11	53	184	249	486	53	190	254	497	0	1	*	1
Swordfish	0	1	1	2	22	33	153	208	22	34	154	210	0	*	0	*
Black marlin	0	6	2	8	3	106	151	260	3	112	153	268	0	1	*	1
Spearfish & sailfish	0	2	2	4	18	87	260	365	18	89	262	369	0	*	*	*
Total billfishes	0	55	27	82	182	1246	1407	2835	182	1301	1434	2917	0	5	*	5
							Annual catch[2]									
Wahoo	0	1	6	7	3	36	179	218	3	37	185	225	0	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 41.--Estimated catch and effort by foreign longliners based at American Samoa, 1971.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
							Monthly nominal effort[1]									
January	1	114	128	243	20	985	1018	2023	21	1099	1146	2266	*	15	15	30
February	0	69	23	92	14	953	1053	2020	14	1022	1076	2112	0	13	5	18
March	0	37	10	47	26	1157	881	2064	26	1194	891	2111	0	10	*	10
April	0	17	1	18	11	1275	1061	2347	11	1292	1062	2365	0	1	0	1
May	0	33	*	33	53	1145	1475	2673	53	1178	1475	2706	0	9	0	9
June	0	18	1	19	76	1267	1518	2861	76	1285	1519	2880	0	5	*	5
July	0	20	1	21	68	1565	1578	3211	68	1585	1579	3232	0	3	*	3
August	0	1	4	5	45	1313	1514	2872	45	1314	1518	2877	0	*	*	*
September	0	18	1	19	57	1095	1061	2213	57	1113	1062	2232	0	4	0	4
October	0	35	3	38	77	1226	1126	2429	77	1261	1129	2467	0	*	0	*
November	0	105	7	112	34	1208	1418	2660	34	1313	1425	2772	0	5	0	5
December	0	119	3	122	40	1094	1392	2526	40	1213	1395	2648	0	21	*	21
Total	1	586	182	769	521	14283	15095	29899	522	14869	15277	30668	*	86	20	106
							Annual catch[2]									
Albacore	*	293	79	372	379	9660	11690	21729	379	9953	11769	22101	*	37	8	45
Yellowfin tuna	*	74	14	88	86	5270	4392	9748	86	5344	4406	9836	*	8	1	9
Bigeye tuna	*	22	2	24	10	1268	1088	2366	10	1290	1090	2390	*	3	*	3
Bluefin tuna	0	*	*	*	*	39	15	54	*	39	15	54	0	*	0	*
Skipjack tuna	*	*	*	*	2	20	60	82	2	20	60	82	*	*	*	*
Total tunas	*	389	95	484	477	16257	17245	33979	477	16646	17340	34463	*	48	9	57
							Annual catch[2]									
Blue marlin	*	73	22	95	95	1148	1235	2478	95	1221	1257	2573	*	15	4	19
Striped marlin	0	10	5	15	34	426	859	1319	34	436	864	1334	0	1	1	2
Swordfish	0	1	1	2	17	63	385	465	17	64	386	467	0	*	*	*
Black marlin	0	5	2	7	1	126	516	643	1	131	518	650	0	3	*	3
Spearfish & sailfish	0	*	3	3	3	61	1029	1093	3	61	1032	1096	0	0	1	1
Total billfishes	*	89	33	122	150	1824	4024	5998	150	1913	4057	6120	*	19	6	25
							Annual catch[2]									
Wahoo	0	5	1	6	9	28	253	290	9	33	254	296	0	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 42.--Estimated catch and effort by foreign longliners based at American Samoa, 1972.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	89	1	90	72	1200	1168	2440	72	1289	1169	2530	0	13	0	13
February	0	91	0	91	20	1281	1229	2530	20	1372	1229	2621	0	16	0	16
March	0	8	3	11	27	1655	1129	2811	27	1663	1132	2822	0	0	0	0
April	0	28	4	32	0	1723	1134	2857	0	1751	1138	2889	0	1	0	1
May	0	25	0	25	0	1763	1448	3211	0	1788	1448	3236	0	*	0	*
June	0	12	0	12	0	1424	1466	2890	0	1436	1466	2902	0	*	0	*
July	0	21	1	22	0	1374	1858	3232	0	1395	1859	3254	0	*	0	*
August	0	70	2	72	0	1229	1468	2697	0	1299	1470	2769	0	5	0	5
September	0	10	4	14	0	1095	1070	2165	0	1105	1074	2179	0	1	2	3
October	0	7	0	7	0	1031	946	1977	0	1038	946	1984	0	1	0	1
November	0	39	2	41	0	936	1181	2117	0	975	1183	2158	0	2	0	2
December	0	42	3	45	0	1221	1177	2398	0	1263	1180	2443	0	6	2	8
Total	0	442	20	462	119	15932	15274	31325	119	16374	15294	31787	0	45	4	49
								Annual catch[2]								
Albacore	0	170	6	176	60	10083	9849	19992	60	10253	9855	20168	0	19	1	20
Yellowfin tuna	0	81	9	90	63	6862	7679	14604	63	6943	7688	14694	0	8	1	9
Bigeye tuna	0	26	1	27	8	2296	1320	3624	8	2322	1321	3651	0	2	*	2
Bluefin tuna	0	*	0	*	0	16	17	33	0	16	17	33	0	0	0	0
Skipjack tuna	0	*	*	*	*	10	76	86	*	10	76	86	0	*	*	*
Total tunas	0	277	16	293	131	19267	18941	38339	131	19544	18957	38632	0	29	2	31
								Annual catch[2]								
Blue marlin	0	56	13	69	268	1172	3996	5436	268	1228	4009	5505	0	8	3	11
Striped marlin	0	8	3	11	12	437	3216	3665	12	445	3219	3676	0	*	*	*
Swordfish	0	2	3	5	8	80	1250	1338	8	82	1253	1343	0	*	1	1
Black marlin	0	6	2	8	4	165	1639	1808	4	171	1641	1815	0	1	0	1
Spearfish & sailfish	0	2	1	3	3	58	3106	3167	3	60	3107	3170	0	*	0	*
Total billfishes	0	74	22	96	295	1912	13207	15414	295	1986	13229	15510	0	9	4	13
								Annual catch[2]								
Wahoo	0	0	*	*	1	24	166	191	1	24	166	191	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 43.--Estimated catch and effort by foreign longliners based at American Samoa, 1973.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	37	4	41	0	1208	1290	2498	0	1245	1294	2539	0	3	0	3
February	0	72	13	85	0	1119	1279	2398	0	1191	1292	2483	0	1	0	1
March	0	25	3	28	0	1382	1448	2830	0	1407	1451	2858	0	1	0	1
April	0	68	7	75	0	1707	1946	3653	0	1775	1953	3728	0	14	*	14
May	0	20	15	35	0	2069	2951	5020	0	2089	2966	5055	0	0	0	0
June	0	42	32	74	0	2221	2851	5072	0	2263	2883	5146	0	0	0	0
July	0	28	11	39	0	2474	2684	5158	0	2502	2695	5197	0	1	1	2
August	0	38	0	38	0	2229	2793	5022	0	2267	2793	5060	0	1	0	1
September	0	65	10	75	0	1381	2365	3746	0	1446	2375	3821	0	14	0	14
October	0	66	35	101	0	1311	2115	3426	0	1377	2150	3527	0	1	1	2
November	0	109	12	121	0	1452	2367	3819	0	1561	2379	3940	0	11	6	17
December	0	173	2	175	0	1505	2468	3973	0	1678	2470	4148	0	30	1	31
Total	0	743	144	887	0	20058	26557	46615	0	20801	26701	47502	0	77	9	86
								Annual catch[2]								
Albacore	0	268	39	307	0	13118	16723	29841	0	13386	16762	30148	0	24	2	26
Yellowfin tuna	0	105	39	144	0	4296	7612	11908	0	4401	7651	12052	0	11	1	12
Bigeye tuna	0	35	9	44	0	2253	2918	5171	0	2288	2927	5215	0	3	*	3
Bluefin tuna	0	*	*	*	0	19	49	68	0	19	49	68	0	*	0	*
Skipjack tuna	0	1	*	1	0	22	107	129	0	23	107	130	0	*	*	*
Total tunas	0	409	87	496	0	19708	27409	47117	0	20117	27496	47613	0	38	3	41
								Annual catch[2]								
Blue marlin	0	93	13	106	0	1326	2393	3719	0	1419	2406	3825	0	12	*	12
Striped marlin	0	8	13	21	0	510	1785	2295	0	518	1798	2316	0	1	*	1
Swordfish	0	3	9	12	0	95	693	788	0	98	702	800	0	1	0	1
Black marlin	0	4	6	10	0	207	1090	1297	0	211	1096	1307	0	*	1	1
Spearfish & sailfish	0	4	2	6	0	124	1432	1556	0	128	1434	1562	0	1	*	1
Total billfishes	0	112	43	155	0	2262	7393	9655	0	2374	7436	9810	0	15	1	16
								Annual catch[2]								
Wahoo	0	2	1	3	0	32	380	412	0	34	381	415	0	1	0	1

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 44.--Estimated catch and effort by foreign longliners based at American Samoa, 1974.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	111	12	123	0	1137	1562	2699	0	1248	1574	2822	0	27	4	31
February	0	64	5	69	0	801	1335	2136	0	865	1340	2205	0	15	*	15
March	0	35	1	36	0	949	1470	2419	0	984	1471	2455	0	1	0	1
April	0	42	*	42	0	1498	1822	3320	0	1540	1822	3362	0	5	0	5
May	0	74	1	75	0	2131	1842	3973	0	2205	1843	4048	0	30	0	30
June	0	204	17	221	0	1705	1712	3417	0	1909	1729	3638	0	78	15	93
July	0	47	5	52	0	1729	1881	3610	0	1776	1886	3662	0	32	1	33
August	0	36	1	37	0	999	1475	2474	0	1035	1476	2511	0	18	*	18
September	0	45	22	67	0	926	1094	2020	0	971	1116	2087	0	12	1	13
October	0	118	21	139	0	1270	1475	2745	0	1388	1496	2884	0	15	1	16
November	0	125	34	159	0	1622	1553	3175	0	1747	1587	3334	0	18	1	19
December	0	27	9	36	0	1545	1724	3269	0	1572	1733	3305	0	1	*	1
Total	0	928	128	1056	0	16312	18945	35257	0	17240	19073	36313	0	252	23	275
								Annual catch[2]								
Albacore	0	266	22	288	0	7598	6755	14353	0	7864	6777	14641	0	76	5	81
Yellowfin tuna	0	125	24	149	0	2275	5945	8220	0	2400	5969	8369	0	50	15	65
Bigeye tuna	0	55	5	60	0	1416	2474	3890	0	1471	2479	3950	0	12	1	13
Bluefin tuna	0	*	*	*	0	18	34	52	0	18	34	52	0	*	0	*
Skipjack tuna	0	1	*	1	0	7	48	55	0	8	48	56	0	*	*	*
Total tunas	0	447	51	498	0	11314	15256	26570	0	11761	15307	27068	0	138	21	159
								Annual catch[2]								
Blue marlin	0	71	18	89	0	720	1528	2248	0	791	1546	2337	0	21	8	29
Striped marlin	0	14	4	18	0	304	1139	1443	0	318	1143	1461	0	3	1	4
Swordfish	0	3	1	4	0	98	437	535	0	101	438	539	0	1	*	1
Black marlin	0	11	3	14	0	124	814	938	0	135	817	952	0	4	1	5
Spearfish & sailfish	0	7	2	9	0	69	798	867	0	76	800	876	0	4	*	4
Total billfishes	0	106	28	134	0	1315	4716	6031	0	1421	4744	6165	0	33	10	43
								Annual catch[2]								
Wahoo	0	2	1	3	0	32	357	389	0	34	358	392	0	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 45.--Estimated catch and effort by foreign longliners based at American Samoa, 1975.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	36	23	59	0	1145	1644	2789	0	1181	1667	2848	0	0	17	17
February	0	34	29	63	0	696	1129	1825	0	730	1158	1888	0	13	*	13
March	0	4	32	36	0	603	1344	1947	0	607	1376	1983	0	0	2	2
April	0	1	2	3	0	755	1329	2084	0	756	1331	2087	0	0	0	0
May	0	8	4	12	0	963	1183	2146	0	971	1187	2158	0	*	2	2
June	0	20	1	21	0	748	1215	1963	0	768	1216	1984	0	0	0	0
July	0	6	*	6	0	655	1404	2059	0	661	1404	2065	0	*	0	*
August	0	10	25	35	0	578	1143	1721	0	588	1168	1756	0	2	6	8
September	0	38	26	64	0	571	970	1541	0	609	996	1605	0	0	1	1
October	0	209	33	242	0	427	926	1353	0	636	959	1595	0	59	10	69
November	0	178	41	219	0	300	989	1289	0	478	1030	1508	0	58	9	67
December	0	31	64	95	0	366	935	1301	0	397	999	1396	0	3	30	33
Total	0	575	280	855	0	7807	14211	22018	0	8382	14491	22873	0	135	77	212
								Annual catch[2]								
Albacore	0	347	86	433	0	3981	3426	7407	0	4328	3512	7840	0	87	27	114
Yellowfin tuna	0	29	43	72	0	1782	5209	6991	0	1811	5252	7063	0	5	16	21
Bigeye tuna	0	26	31	57	0	935	4053	4988	0	961	4084	5045	0	4	5	9
Bluefin tuna	0	*	*	*	0	4	18	22	0	4	18	22	0	*	*	*
Skipjack tuna	0	*	*	*	0	4	13	17	0	4	13	17	0	*	*	*
Total tunas	0	402	160	562	0	6706	12719	19425	0	7108	12879	19987	0	96	48	144
								Annual catch[2]								
Blue marlin	0	21	17	38	0	259	673	932	0	280	690	970	0	5	5	10
Striped marlin	0	6	25	31	0	115	752	867	0	121	777	898	0	1	9	10
Swordfish	0	3	4	7	0	25	287	312	0	28	291	319	0	1	1	2
Black marlin	0	3	25	28	0	44	468	512	0	47	493	540	0	1	7	8
Spearfish & sailfish	0	1	5	6	0	16	559	575	0	17	564	581	0	*	1	1
Total billfishes	0	34	76	110	0	459	2739	3198	0	493	2815	3308	0	8	23	31
								Annual catch[2]								
Wahoo	0	1	1	2	0	10	131	141	0	11	132	143	0	*	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 46.--Estimated catch and effort by foreign longliners based at American Samoa, 1976.

	Inside FCZ (A)				Outside FCZ (B)				Entire area (A+B)				Within 50 mi.			
	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total	Japan	Taiwan	Korea	Total
								Monthly nominal effort[1]								
January	0	64	45	109	0	375	1033	1408	0	439	1078	1517	0	5	8	13
February	0	32	28	60	0	415	866	1281	0	447	894	1341	0	2	2	4
March	0	19	33	52	0	361	1153	1514	0	380	1186	1566	0	1	7	8
April	0	10	16	26	0	350	1022	1372	0	360	1038	1398	0	1	2	3
May	0	15	20	35	0	441	1275	1716	0	456	1295	1751	0	9	1	10
June	0	1	7	8	0	521	1371	1892	0	522	1378	1900	0	0	0	0
July	0	20	5	25	0	678	1561	2239	0	698	1566	2264	0	13	0	13
August	0	19	4	23	0	624	1540	2164	0	643	1544	2187	0	4	1	5
September	0	51	8	59	0	748	999	1747	0	799	1007	1806	0	8	1	9
October	0	92	21	113	0	860	1353	2213	0	952	1374	2326	0	10	2	12
November	0	153	30	183	0	890	1368	2258	0	1043	1398	2441	0	13	9	22
December	0	118	8	126	0	968	1528	2496	0	1086	1536	2622	0	19	0	19
Total	0	594	225	819	0	7231	15069	22300	0	7825	15294	23119	0	85	33	118
								Annual catch[2]								
Albacore	0	328	54	382	0	5763	8382	14145	0	6091	8436	14527	0	39	8	47
Yellowfin tuna	0	67	49	116	0	1374	5559	6933	0	1441	5608	7049	0	15	5	20
Bigeye tuna	0	29	48	77	0	629	3371	4000	0	658	3419	4077	0	5	3	8
Bluefin tuna	0	*	*	*	0	3	14	17	0	3	14	17	0	*	0	*
Skipjack tuna	0	*	*	*	0	5	16	21	0	5	16	21	0	*	*	*
Total tunas	0	424	151	575	0	7774	17342	25116	0	8198	17493	25691	0	59	16	75
								Annual catch[2]								
Blue marlin	0	44	12	56	0	256	764	1020	0	300	776	1076	0	7	1	8
Striped marlin	0	4	7	11	0	120	448	568	0	124	455	579	0	1	1	2
Swordfish	0	2	7	9	0	45	266	311	0	47	273	320	0	1	1	2
Black marlin	0	3	10	13	0	58	464	522	0	61	474	535	0	*	1	1
Spearfish & sailfish	0	3	13	16	0	49	605	654	0	52	618	670	0	*	1	1
Total billfishes	0	56	49	105	0	528	2547	3075	0	584	2596	3180	0	9	5	14
								Annual catch[2]								
Wahoo	0	2	11	13	0	24	311	335	0	26	322	348	0	*	1	1

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 47.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1965.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	18	165	105	10	67	365
February	19	58	60	3	186	326
March	7	5	103	9	152	276
April	8	23	74	27	40	172
May	32	41	93	87	64	317
June	5	5	7	121	278	416
July	6	0	83	91	123	303
August	1	0	87	105	51	244
September	8	1	45	114	123	291
October	12	3	15	3	42	75
November	5	29	38	24	*	96
December	3	10	21	0	*	34
Total	124	340	731	594	1126	2915
			Annual catch[2]			
Albacore	14	10	1	16	47	88
Yellowfin tuna	13	150	368	614	977	2122
Bigeye tuna	17	230	372	195	400	1214
Bluefin tuna	*	*	*	*	*	*
Skipjack tuna	*	1	4	5	8	18
Total tunas	44	391	745	830	1432	3442
			Annual catch[2]			
Blue marlin	11	43	76	52	116	298
Striped marlin	44	54	46	3	8	155
Swordfish	5	3	11	11	6	36
Black marlin	*	2	6	6	9	23
Spearfish & sailfish	3	3	9	11	9	35
Total billfishes	63	105	148	83	148	547

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 48.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1966.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	16	39	15	5	4	79
February	7	21	81	2	13	124
March	6	8	29	5	19	67
April	*	42	57	7	*	106
May	3	40	126	36	12	217
June	2	*	17	34	171	224
July	0	0	5	14	168	187
August	0	0	54	15	51	120
September	0	2	17	4	55	78
October	0	4	7	22	89	122
November	0	21	0	20	51	92
December	2	27	*	1	28	58
Total	36	204	408	165	661	1474
			Annual catch[2]			
Albacore	17	6	1	15	25	64
Yellowfin tuna	6	69	166	121	724	1086
Bigeye tuna	10	216	270	58	194	748
Bluefin tuna	0	0	*	*	*	*
Skipjack tuna	*	2	1	1	3	7
Total tunas	33	293	438	195	946	1905
			Annual catch[2]			
Blue marlin	2	35	43	11	82	173
Striped marlin	2	29	17	1	4	53
Swordfish	1	2	5	3	8	19
Black marlin	*	1	3	2	8	14
Spearfish & sailfish	*	3	7	4	12	26
Total billfishes	5	70	75	21	114	285

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 49.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1967.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	10	34	7	2	7	60
February	28	51	142	1	9	231
March	35	4	262	*	40	341
April	5	132	71	7	21	236
May	16	15	91	40	134	296
June	13	1	4	21	141	180
July	6	0	67	69	25	167
August	*	0	67	27	13	107
September	*	0	44	24	38	106
October	1	*	8	2	80	91
November	0	23	5	3	10	41
December	0	11	109	4	2	126
Total	114	271	877	200	520	1982
			Annual catch[2]			
Albacore	66	14	1	2	9	92
Yellowfin tuna	5	80	380	179	455	1099
Bigeye tuna	9	302	614	73	150	1148
Bluefin tuna	*	0	0	*	0	*
Skipjack tuna	*	*	3	1	2	6
Total tunas	80	396	998	255	616	2345
			Annual catch[2]			
Blue marlin	9	65	96	22	63	255
Striped marlin	11	25	43	2	1	82
Swordfish	4	4	20	4	4	36
Black marlin	*	1	5	2	5	13
Spearfish & sailfish	4	5	20	3	9	41
Total billfishes	28	100	184	33	82	427

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 50.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1968.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	5	11	83	2	1	102
February	3	35	38	52	*	128
March	12	22	55	52	20	161
April	9	13	51	135	35	243
May	24	4	55	63	93	239
June	12	2	77	82	100	273
July	46	2	26	25	71	170
August	38	0	44	8	34	124
September	0	*	25	2	10	37
October	2	*	5	13	16	36
November	12	1	0	6	18	37
December	34	*	5	10	5	54
Total	197	90	464	450	403	1604
			Annual catch[2]			
Albacore	37	4	*	10	12	63
Yellowfin tuna	26	29	277	340	331	1003
Bigeye tuna	38	81	217	187	117	640
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	*	*	6	9	2	17
Total tunas	101	114	500	546	462	1723
			Annual catch[2]			
Blue marlin	36	21	51	31	44	183
Striped marlin	24	9	17	3	5	58
Swordfish	2	1	6	11	4	24
Black marlin	*	*	3	3	3	9
Spearfish & sailfish	7	1	13	14	2	37
Total billfishes	69	32	90	62	58	311

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 51.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1969.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	3	27	4	25	9	68
February	4	8	246	33	38	329
March	5	17	111	21	126	280
April	2	48	33	38	29	150
May	18	12	82	23	62	197
June	2	1	211	51	32	297
July	0	1	42	13	53	109
August	2	0	3	2	7	14
September	1	*	1	1	45	48
October	14	1	16	12	48	91
November	7	25	37	11	35	115
December	0	20	5	7	88	120
Total	58	160	791	237	572	1818
			Annual catch[2]			
Albacore	6	11	1	5	13	36
Yellowfin tuna	19	45	353	218	498	1133
Bigeye tuna	12	187	613	101	203	1116
Bluefin tuna	0	0	*	*	0	*
Skipjack tuna	*	1	3	3	1	8
Total tunas	37	244	970	327	715	2293
			Annual catch[2]			
Blue marlin	6	34	100	21	57	218
Striped marlin	6	13	24	3	4	50
Swordfish	1	2	13	6	5	27
Black marlin	*	*	6	1	3	10
Spearfish & sailfish	*	6	10	3	3	22
Total billfishes	13	55	153	34	72	327

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 52.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1970.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	16	15	0	15	46
February	16	46	168	8	12	250
March	1	55	219	6	15	296
April	0	67	235	12	8	322
May	3	25	100	36	2	166
June	4	11	162	52	47	276
July	7	5	47	46	94	199
August	15	1	78	72	99	265
September	14	8	21	5	209	257
October	10	5	16	13	47	91
November	0	61	1	*	0	82
December	1	40	15	1	15	72
Total	71	360	1077	251	563	2322
			Annual catch[2]			
Albacore	15	16	2	2	2	37
Yellowfin tuna	16	202	879	253	466	1816
Bigeye tuna	14	351	595	74	153	1187
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	1	2	12	2	2	19
Total tunas	46	571	1488	331	623	3059
			Annual catch[2]			
Blue marlin	17	99	144	24	66	350
Striped marlin	3	40	32	2	4	81
Swordfish	1	5	20	5	6	37
Black marlin	*	1	5	2	3	11
Spearfish & sailfish	1	10	14	4	4	33
Total billfishes	22	155	215	37	83	512

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 53.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1971.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	14	44	*	16	74
February	3	73	68	2	5	151
March	26	28	283	7	26	370
April	17	64	57	28	*	166
May	2	36	110	92	86	326
June	18	11	57	59	264	409
July	8	28	73	53	92	254
August	10	6	45	34	26	121
September	0	18	29	4	1	52
October	15	14	17	2	26	74
November	0	8	57	0	3	68
December	14	10	34	0	0	58
Total	113	310	874	281	545	2123
			Annual catch[2]			
Albacore	40	6	1	3	2	52
Yellowfin tuna	19	66	260	169	397	911
Bigeye tuna	18	279	469	116	188	1070
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	1	4	1	2	8
Total tunas	77	352	734	289	589	2041
			Annual catch[2]			
Blue marlin	22	53	49	9	35	168
Striped marlin	4	18	45	1	4	72
Swordfish	1	7	20	6	10	44
Black marlin	*	1	3	1	5	10
Spearfish & sailfish	*	4	13	3	5	25
Total billfishes	27	83	130	20	59	319

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 54.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1972.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	1	3	81	0	0	85
February	7	1	39	*	25	72
March	*	44	134	1	17	196
April	4	31	208	22	3	268
May	7	69	65	24	81	246
June	*	30	144	88	75	337
July	0	24	152	108	93	377
August	0	33	64	63	153	313
September	1	3	45	34	159	242
October	0	3	88	25	35	151
November	0	9	11	5	4	29
December	*	19	15	0	10	44
Total	20	269	1046	370	655	2360
			Annual catch[2]			
Albacore	2	12	*	3	1	18
Yellowfin tuna	3	43	515	269	424	1254
Bigeye tuna	3	252	521	149	328	1253
Bluefin tuna	*	0	0	0	*	*
Skipjack tuna	0	1	3	2	1	7
Total tunas	8	308	1039	423	754	2532
			Annual catch[2]			
Blue marlin	2	72	114	40	88	316
Striped marlin	2	18	19	2	3	44
Swordfish	1	8	25	8	7	49
Black marlin	1	1	8	3	12	25
Spearfish & sailfish	*	4	6	2	3	15
Total billfishes	6	103	172	55	113	449

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 55.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1973.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	54	77	1	13	145
February	2	37	62	1	2	104
March	15	66	270	1	16	368
April	10	54	135	2	3	204
May	4	23	26	8	13	74
June	0	34	21	7	18	80
July	0	6	21	19	83	129
August	0	5	49	25	35	114
September	0	10	12	3	4	29
October	0	11	1	0	5	17
November	0	20	1	3	0	24
December	0	25	0	0	4	29
Total	31	345	675	70	196	1317
			Annual catch[2]			
Albacore	4	19	*	1	1	25
Yellowfin tuna	3	80	78	21	94	276
Bigeye tuna	7	303	360	48	80	798
Bluefin tuna	0	*	0	0	*	*
Skipjack tuna	*	1	1	*	*	2
Total tunas	14	403	439	70	175	1101
			Annual catch[2]			
Blue marlin	3	46	44	2	12	107
Striped marlin	3	16	25	1	1	46
Swordfish	3	7	31	2	2	45
Black marlin	*	2	2	*	2	6
Spearfish & sailfish	1	6	7	1	2	17
Total billfishes	10	77	109	6	19	221

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 56.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1974.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	34	46	*	8	88
February	6	54	181	1	1	243
March	15	63	94	3	3	178
April	8	302	281	5	2	598
May	14	94	75	17	7	207
June	4	8	38	31	42	123
July	2	30	46	29	89	196
August	*	41	7	1	70	119
September	3	24	8	8	8	51
October	0	15	31	27	36	109
November	2	56	35	4	6	103
December	5	80	1	0	52	138
Total	59	801	843	126	324	2153
			Annual catch[2]			
Albacore	5	49	1	*	*	55
Yellowfin tuna	4	148	188	39	98	477
Bigeye tuna	10	380	373	46	149	958
Bluefin tuna	0	*	0	0	0	*
Skipjack tuna	*	2	2	*	*	4
Total tunas	19	579	564	85	247	1494
			Annual catch[2]			
Blue marlin	4	61	61	7	13	146
Striped marlin	6	11	15	1	1	34
Swordfish	5	9	32	2	4	52
Black marlin	*	1	4	*	1	6
Spearfish & sailfish	*	7	5	2	2	16
Total billfishes	15	89	117	12	21	254

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 57.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1975.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	15	32	67	1	18	133
February	67	123	49	0	26	265
March	21	54	61	3	36	175
April	4	42	35	0	2	83
May	0	36	17	3	0	56
June	0	17	4	0	26	47
July	0	3	0	0	52	55
August	0	10	3	10	26	49
September	0	23	7	16	96	142
October	0	31	4	9	77	121
November	10	23	0	16	*	49
December	1	15	6	13	*	35
Total	118	409	253	71	359	1210
			Annual catch[2]			
Albacore	11	27	*	3	2	43
Yellowfin tuna	12	85	43	16	120	276
Bigeye tuna	53	319	102	39	136	649
Bluefin tuna	0	*	0	0	0	*
Skipjack tuna	*	*	1	*	*	1
Total tunas	76	431	146	58	258	969
			Annual catch[2]			
Blue marlin	3	17	7	2	8	37
Striped marlin	4	13	8	*	2	27
Swordfish	7	7	6	2	3	25
Black marlin	*	*	1	*	*	1
Spearfish & sailfish	1	4	5	3	1	14
Total billfishes	15	41	27	7	14	104

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 58.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1976.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	7	19	11	11	47	95
February	24	57	7	0	26	114
March	19	49	102	1	62	233
April	10	33	77	8	34	162
May	0	29	10	7	64	110
June	0	28	50	35	22	135
July	*	29	53	32	32	146
August	3	29	21	5	12	70
September	0	18	128	4	15	165
October	*	10	31	11	86	138
November	4	1	11	13	15	44
December	*	2	3	0	33	38
Total	67	304	504	127	448	1450
			Annual catch[2]			
Albacore	16	16	1	1	1	35
Yellowfin tuna	6	68	119	67	275	535
Bigeye tuna	18	265	204	44	161	692
Bluefin tuna	0	*	0	0	*	*
Skipjack tuna	*	*	1	*	*	1
Total tunas	40	349	325	112	437	1263
			Annual catch[2]			
Blue marlin	3	34	48	9	31	125
Striped marlin	3	10	28	1	1	43
Swordfish	8	9	12	3	6	38
Black marlin	*	1	1	*	1	3
Spearfish & sailfish	1	3	5	1	1	11
Total billfishes	15	57	94	14	40	220

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 59.--Estimated catch and effort by Japanese longliners in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1977.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	96	11	*	*	104	211
February	64	35	48	0	36	183
March	17	73	31	1	99	221
April	4	20	34	1	21	80
May	0	37	11	1	6	55
June	*	55	1	*	7	63
July	0	14	2	1	31	48
August	0	4	8	15	7	34
September	0	*	3	3	54	60
October	0	*	0	3	152	155
November	*	*	1	*	129	130
December	7	6	33	4	78	128
Total	188	255	172	29	724	1368
			Annual catch[2]			
Albacore	57	14	1	1	7	80
Yellowfin tuna	7	41	39	12	609	708
Bigeye tuna	78	276	98	17	338	807
Bluefin tuna	*	0	0	0	0	*
Skipjack tuna	*	*	1	*	*	1
Total tunas	142	331	139	30	954	1596
			Annual catch[2]			
Blue marlin	4	23	8	2	56	93
Striped marlin	3	7	2	*	2	14
Swordfish	9	8	3	*	11	31
Black marlin	*	*	1	*	3	4
Spearfish & sailfish	*	1	*	*	2	3
Total billfishes	16	39	14	2	74	145

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 60.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1967.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	26	0	26
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	16	55	10	81
September	0	10	0	10	9	29
October	0	56	0	0	0	56
November	0	1	0	29	0	30
December	0	0	0	0	0	0
Total	0	67	16	120	19	222
			Annual catch[2]			
Albacore	0	103	32	201	32	368
Yellowfin tuna	0	27	8	74	4	113
Bigeye tuna	0	34	10	81	6	131
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	164	50	356	42	612
			Annual catch[2]			
Blue marlin	0	3	0	11	1	15
Striped marlin	0	0	*	1	0	1
Swordfish	0	1	0	1	*	2
Black marlin	0	*	0	0	*	*
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	0	4	*	13	1	18

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 61.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1968.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	1	1
February	0	3	0	18	24	45
March	0	0	0	20	12	32
April	0	0	0	58	19	77
May	0	0	0	46	*	46
June	0	10	0	2	10	22
July	0	0	3	4	33	40
August	0	0	0	0	46	46
September	0	0	0	2	17	19
October	0	0	1	31	14	46
November	0	0	2	30	17	49
December	0	0	0	3	6	9
Total	0	13	6	214	199	432
			Annual catch[2]			
Albacore	0	31	5	320	163	519
Yellowfin tuna	0	13	4	73	257	347
Bigeye tuna	0	5	2	34	51	92
Bluefin tuna	0	*	0	1	21	22
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	49	11	428	492	980
			Annual catch[2]			
Blue marlin	0	2	*	12	9	23
Striped marlin	0	*	0	2	*	2
Swordfish	0	1	0	*	1	2
Black marlin	0	0	0	1	1	2
Spearfish & sailfish	0	0	0	0	*	*
Total billfishes	0	3	*	15	11	29

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 62.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1969.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	52	52
February	0	0	0	0	2	2
March	0	0	0	0	21	21
April	0	0	0	0	1	1
May	0	0	0	0	0	0
June	0	0	0	0	17	17
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	33	0	0	33
Total	0	0	33	0	93	126
			Annual catch[2]			
Albacore	0	0	21	0	73	94
Yellowfin tuna	0	0	27	0	52	79
Bigeye tuna	0	0	6	0	12	18
Bluefin tuna	0	0	0	0	4	4
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	0	54	0	141	195
			Annual catch[2]			
Blue marlin	0	0	2	0	8	10
Striped marlin	0	0	0	0	*	*
Swordfish	0	0	0	0	*	*
Black marlin	0	0	0	0	2	2
Spearfish & sailfish	0	0	0	0	1	1
Total billfishes	0	0	2	0	11	13

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 63.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1970.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	23	0	0	23
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	7	7
June	0	0	0	*	10	10
July	0	0	0	0	0	0
August	0	0	0	0	6	6
September	0	0	0	0	0	0
October	0	0	0	0	1	1
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	0	0	23	*	24	47
			Annual catch[2]			
Albacore	0	0	21	*	23	44
Yellowfin tuna	0	0	19	*	16	35
Bigeye tuna	0	0	8	*	6	14
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	0	48	*	45	93
			Annual catch[2]			
Blue marlin	0	0	1	0	1	2
Striped marlin	0	0	0	0	*	*
Swordfish	0	0	*	0	*	*
Black marlin	0	0	*	0	*	*
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	0	0	1	0	1	2

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 64.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1971.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	5	5
February	0	0	0	0	2	2
March	0	0	0	0	8	8
April	0	0	0	2	14	16
May	0	0	0	0	19	19
June	0	0	0	0	7	7
July	0	0	0	0	19	19
August	0	0	0	0	5	5
September	0	0	0	0	4	4
October	0	0	0	0	1	1
November	0	0	0	0	1	1
December	0	0	0	0	0	0
Total	0	0	0	2	85	87
			Annual catch[2]			
Albacore	0	0	0	1	63	64
Yellowfin tuna	0	0	0	2	133	135
Bigeye tuna	0	0	0	*	29	29
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	0	0	3	225	228
			Annual catch[2]			
Blue marlin	0	0	0	*	2	2
Striped marlin	0	0	0	0	*	*
Swordfish	0	0	0	0	1	1
Black marlin	0	0	0	0	0	0
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	0	0	0	*	3	3

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 65.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1972.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	7	7
February	0	0	0	0	9	9
March	0	0	0	1	0	1
April	0	0	0	3	17	20
May	0	0	0	0	22	22
June	0	0	0	0	10	10
July	0	0	0	0	1	1
August	0	0	0	0	2	2
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	0	0	0	4	68	72
			Annual catch[2]			
Albacore	0	0	0	1	27	28
Yellowfin tuna	0	0	0	4	87	91
Bigeye tuna	0	0	0	1	23	24
Bluefin tuna	0	0	0	0	*	*
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	0	0	6	137	143
			Annual catch[2]			
Blue marlin	0	0	0	0	2	2
Striped marlin	0	0	0	0	*	*
Swordfish	0	0	0	0	*	*
Black marlin	0	0	0	0	*	*
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	0	0	0	0	2	2

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 66.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1973.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	3	3
February	0	0	0	3	0	3
March	0	0	0	0	2	2
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	0	0	0	3	5	8
			Annual catch[2]			
Albacore	0	0	0	2	1	3
Yellowfin tuna	0	0	0	*	1	1
Bigeye tuna	0	0	0	1	2	3
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	0	0	0	3	4	7
			Annual catch[2]			
Blue marlin	0	0	0	0	*	*
Striped marlin	0	0	0	0	0	0
Swordfish	0	0	0	0	0	0
Black marlin	0	0	0	0	0	0
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	0	0	0	0	*	*

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 67.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1974.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	0	0	0	2	0	2
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	5	5
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	5	0	0	0	0	5
December	42	0	0	0	0	42
Total	47	0	0	2	5	54
			Annual catch[2]			
Albacore	32	0	0	*	*	32
Yellowfin tuna	4	0	0	*	1	5
Bigeye tuna	8	0	0	1	1	10
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	44	0	0	1	2	47
			Annual catch[2]			
Blue marlin	4	0	0	0	0	4
Striped marlin	1	0	0	0	0	1
Swordfish	*	0	0	0	0	*
Black marlin	0	0	0	0	0	0
Spearfish & sailfish	0	0	0	0	0	0
Total billfishes	5	0	0	0	0	5

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 68.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1975.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	216	0	0	0	0	216
February	49	0	0	1	0	50
March	0	0	0	0	0	0
April	0	0	0	0	9	9
May	0	0	0	0	6	6
June	0	0	0	1	6	7
July	0	0	0	0	1	1
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	34	0	0	0	0	34
November	108	0	0	0	0	108
December	58	0	0	0	0	58
Total	465	0	0	2	22	489
			Annual catch[2]			
Albacore	427	0	0	*	6	433
Yellowfin tuna	72	0	0	1	11	84
Bigeye tuna	31	0	0	1	8	40
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	0	0	0	0	0	0
Total tunas	530	0	0	2	25	557
			Annual catch[2]			
Blue marlin	36	0	0	0	1	37
Striped marlin	9	0	0	0	0	9
Swordfish	5	0	0	*	0	5
Black marlin	3	0	0	0	0	3
Spearfish & sailfish	2	0	0	0	0	2
Total billfishes	55	0	0	*	1	56

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 69.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1976.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	69	0	0	0	0	69
March	147	0	0	0	0	147
April	0	0	0	0	17	17
May	0	0	0	0	0	0
June	0	0	0	0	5	5
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	26	0	0	0	0	26
December	0	0	0	0	0	0
Total	242	0	0	0	22	264
			Annual catch[2]			
Albacore	210	0	0	0	8	218
Yellowfin tuna	51	0	0	0	16	67
Bigeye tuna	15	0	0	0	4	19
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	4	0	0	0	0	4
Total tunas	280	0	0	0	28	308
			Annual catch[2]			
Blue marlin	21	0	0	0	1	22
Striped marlin	5	0	0	0	0	5
Swordfish	*	0	0	0	0	*
Black marlin	0	0	0	0	0	0
Spearfish & sailfish	109	0	0	0	1	110
Total billfishes	135	0	0	0	2	137

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 70.--Estimated catch and effort by longliners of Taiwan in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1977.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	1	*	0	38	39
February	58	0	0	0	2	60
March	4	0	*	3	0	7
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	*	*
September	0	0	0	0	0	0
October	0	0	0	3	0	3
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	62	1	*	6	40	109
			Annual catch[2]			
Albacore	42	*	0	2	*	44
Yellowfin tuna	5	*	*	1	53	59
Bigeye tuna	2	1	*	2	5	10
Bluefin tuna	0	0	0	*	0	*
Skipjack tuna	*	0	0	0	0	*
Total tunas	49	1	*	5	58	113
			Annual catch[2]			
Blue marlin	2	0	0	*	1	3
Striped marlin	1	*	0	0	0	1
Swordfish	*	0	0	0	*	*
Black marlin	0	0	0	0	0	0
Spearfish & sailfish	*	0	0	0	0	*
Total billfishes	3	*	0	*	1	4

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 71.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1972.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0
August	0	0	0	55	33	24	55	33	24
September	0	0	0	155	132	88	155	132	88
October	0	0	0	3	3	1	3	3	1
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	0	0	0	213	168	113	213	168	113
				Annual catch[2]					
Albacore	0	0	0	26	0	0	26	0	0
Yellowfin tuna	0	0	0	19	3	3	19	3	3
Bigeye tuna	0	0	0	105	63	37	105	63	37
Bluefin tuna	0	0	0	26	8	5	26	8	5
Skipjack tuna	0	0	0	1282	971	636	1282	971	636
Total tunas	0	0	0	1458	1045	681	1458	1045	681
				Annual catch[2]					
Frigate tuna	0	0	0	6	6	4	6	6	4
Others	0	0	0	31	31	22	31	31	22

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 72.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1973.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0
July	0	0	0	59	40	22	59	40	22
August	0	0	0	37	16	8	37	16	8
September	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	0	0	0	96	56	30	96	56	30
				Annual catch[2]					
Albacore	0	0	0	0	0	0	0	0	0
Yellowfin tuna	0	0	0	20	10	10	20	10	10
Bigeye tuna	0	0	0	109	80	43	109	80	43
Bluefin tuna	0	0	0	0	0	0	0	0	0
Skipjack tuna	0	0	0	823	451	192	823	451	192
Total tunas	0	0	0	952	541	245	952	541	245
				Annual catch[2]					
Frigate tuna	0	0	0	0	0	0	0	0	0
Others	0	0	0	12	11	7	12	11	7

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 73.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1974.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0
June	0	0	0	7	4	3	7	4	3
July	0	0	0	83	63	48	83	63	48
August	1	1	1	86	68	38	87	69	39
September	0	0	0	10	7	5	10	7	5
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	1	1	1	186	142	94	187	143	95
				Annual catch[2]					
Albacore	0	0	0	0	0	0	0	0	0
Yellowfin tuna	0	0	0	50	48	36	50	48	36
Bigeye tuna	0	0	0	147	66	47	147	66	47
Bluefin tuna	0	0	0	*	*	*	*	*	*
Skipjack tuna	0	0	0	1971	1593	1107	1971	1593	1107
Total tunas	0	0	0	2168	1707	1190	2168	1707	1190
				Annual catch[2]					
Frigate tuna	0	0	0	6	6	6	6	6	6
Others	0	0	0	19	16	11	19	16	11

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 74.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1975.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	1	0	0	1	0	0
May	0	0	0	12	9	6	12	9	6
June	0	0	0	54	46	32	54	46	32
July	0	0	0	122	82	48	122	82	48
August	0	0	0	51	25	11	51	25	11
September	3	3	2	23	21	10	26	24	12
October	0	0	0	3	1	0	3	1	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	3	3	2	266	184	107	269	187	109
				Annual catch[2]					
Albacore	0	0	0	89	89	27	89	89	27
Yellowfin tuna	0	0	0	167	155	80	167	155	80
Bigeye tuna	0	0	0	71	53	36	71	53	36
Bluefin tuna	0	0	0	25	25	8	25	25	8
Skipjack tuna	0	0	0	1906	1301	804	1906	1301	804
Total tunas	0	0	0	2258	1623	955	2258	1623	955
				Annual catch[2]					
Frigate tuna	0	0	0	11	11	7	11	11	7
Others	0	0	0	83	81	46	83	81	46

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 75.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1976.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0	0	0	1	*	0	1	*	0
June	0	0	0	82	62	35	82	62	35
July	22	10	5	409	354	208	431	364	213
August	29	23	4	97	85	49	126	108	53
September	0	0	0	9	7	5	9	7	5
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	51	33	9	598	508	297	649	541	306
				Annual catch[2]					
Albacore	0	0	0	0	0	0	0	0	0
Yellowfin tuna	54	3	*	124	109	73	178	112	73
Bigeye tuna	89	*	0	92	76	43	181	76	43
Bluefin tuna	0	0	0	0	0	0	0	0	0
Skipjack tuna	315	242	56	4294	3847	2367	4609	4089	2423
Total tunas	458	245	56	4510	4032	2483	4968	4277	2539
				Annual catch[2]					
Frigate tuna	0	0	0	9	8	5	9	8	5
Others	0	0	0	28	27	13	28	27	13

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 76.--Estimated catch and effort by Japanese baitboats within 200, 100, and 50 miles of the Hawaiian Islands, 1977.

	Main Hawaiian Islands (A)			Northwestern Hawaiian Islands (B)			Total Hawaiian Islands (A + B)		
	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.	200 mi.	100 mi.	50 mi.
				Monthly nominal effort[1]					
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	20	16	9	20	16	9
May	0	0	0	14	13	10	14	13	10
June	32	17	12	409	258	165	441	275	177
July	14	10	2	208	65	27	222	75	29
August	6	1	*	36	26	15	42	27	15
September	0	0	0	17	7	4	17	7	4
October	0	0	0	11	5	3	11	5	3
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Total	52	28	14	715	390	233	767	418	247
				Annual catch[2]					
Albacore	0	0	0	49	2	0	49	2	0
Yellowfin tuna	25	*	0	337	253	169	362	253	169
Bigeye tuna	91	1	0	734	654	497	825	655	497
Bluefin tuna	0	0	0	0	0	0	0	0	0
Skipjack tuna	281	153	29	4375	2339	1347	4656	2492	1376
Total tunas	397	154	29	5495	3248	2013	5892	3402	2042
				Annual catch[2]					
Frigate tuna	1	1	*	16	11	6	17	12	6
Others	0	0	0	108	99	68	108	99	68

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 77.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1970.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	1	13	3	38	4	51
February	0	20	8	28	8	48
March	2	71	12	52	14	123
April	2	15	28	65	30	80
May	*	4	14	35	14	39
June	0	0	9	53	9	53
July	0	1	207	602	207	603
August	*	5	78	229	78	234
September	5	28	101	207	106	235
October	0	4	21	54	21	58
November	1	14	41	292	42	306
December	2	7	3	107	5	114
Total	13	182	525	1762	538	1944
	Annual catch[2]					
Albacore	0	0	*	14	*	14
Yellowfin tuna	*	16	54	414	54	430
Bigeye tuna	0	*	35	153	35	153
Bluefin tuna	0	0	1	4	1	4
Skipjack tuna	28	649	2903	8284	2931	8933
Total tunas	28	665	2993	8869	3021	9534
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	*	*	3	13	3	13

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 78.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1971.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	*	20	4	38	4	58
February	*	24	20	74	20	98
March	2	14	14	66	16	80
April	0	1	1	7	1	8
May	0	0	0	8	0	8
June	0	0	14	31	14	31
July	0	1	194	678	194	679
August	4	6	218	562	222	568
September	3	15	255	564	258	579
October	11	44	178	419	189	463
November	0	30	27	173	27	203
December	1	9	4	26	5	35
Total	21	164	929	2646	950	2810
	Annual catch[2]					
Albacore	0	0	0	2	0	2
Yellowfin tuna	*	46	38	184	38	230
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	0	0	0	12	0	12
Skipjack tuna	78	398	4454	12366	4532	12764
Total tunas	78	444	4492	12564	4570	13008
	Annual catch[2]					
Frigate tuna	0	0	*	*	*	*
Others	0	1	1	19	1	20

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 79.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1972.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	1	4	5	17	6	21
February	0	2	9	20	9	22
March	*	2	10	28	10	30
April	0	2	12	47	12	49
May	1	1	3	8	4	9
June	0	0	97	299	97	299
July	3	10	251	527	254	537
August	9	18	188	487	197	505
September	9	17	47	116	56	133
October	2	12	14	45	16	57
November	16	31	10	46	26	77
December	6	19	*	8	6	27
Total	47	118	646	1648	693	1766
	Annual catch[2]					
Albacore	3	13	23	52	26	65
Yellowfin tuna	0	4	17	66	17	70
Bigeye tuna	0	0	4	16	4	16
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	131	284	2885	6971	3016	7255
Total tunas	134	301	2929	7105	3063	7406
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	1	1	1	2	2	3

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 80.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1973.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	2	0	13	0	15
February	*	2	3	18	3	20
March	0	8	6	73	6	81
April	0	6	7	32	7	38
May	0	0	4	14	4	14
June	0	0	13	41	13	41
July	0	5	233	532	233	537
August	8	15	202	470	210	485
September	4	4	49	134	53	138
October	0	1	16	54	16	55
November	1	2	64	140	65	142
December	*	9	27	82	27	91
Total	13	54	624	1603	637	1657
	Annual catch[2]					
Albacore	0	0	9	11	9	11
Yellowfin tuna	7	10	36	258	43	268
Bigeye tuna	0	1	0	6	0	7
Bluefin tuna	0	0	0	4	0	4
Skipjack tuna	78	223	3030	7099	3108	7322
Total tunas	85	234	3075	7378	3160	7612
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	0	0	*	2	*	2

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 81.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1974.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	*	6	26	34	26	40
February	0	3	15	74	15	77
March	*	3	2	55	2	58
April	0	3	20	45	20	48
May	0	0	0	0	0	0
June	0	0	7	26	7	26
July	5	11	195	556	200	567
August	0	2	23	59	23	61
September	3	17	63	127	66	144
October	2	11	107	199	109	210
November	1	8	39	138	40	146
December	1	3	28	62	29	65
Total	12	67	525	1375	537	1442
	Annual catch[2]					
Albacore	0	0	1	1	1	1
Yellowfin tuna	0	7	101	294	101	301
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	8	76	1798	4627	1806	4703
Total tunas	8	83	1900	4922	1908	5005
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	0	0	23	39	23	39

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 82.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1975.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	1	15	44	15	45
February	1	3	22	36	23	39
March	3	20	35	81	38	101
April	4	21	66	137	70	158
May	2	77	5	30	7	107
June	1	9	188	391	189	400
July	1	10	85	254	86	264
August	*	8	132	260	132	268
September	1	22	51	154	52	176
October	*	8	4	56	4	64
November	1	10	52	151	53	161
December	1	17	38	102	39	119
Total	15	206	693	1696	708	1902
	Annual catch[2]					
Albacore	0	0	0	4	0	4
Yellowfin tuna	0	9	82	271	82	280
Bigeye tuna	0	1	2	6	2	7
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	68	1117	2867	6345	2935	7462
Total tunas	68	1127	2951	6626	3019	7753
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	0	3	16	31	16	34

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 83.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1976.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	6	22	78	22	84
February	0	2	7	30	7	32
March	0	0	4	17	4	17
April	*	9	0	14	*	23
May	0	0	1	6	1	6
June	0	0	2	7	2	7
July	1	5	77	264	78	269
August	0	0	25	76	25	76
September	0	3	16	33	16	36
October	2	3	11	35	13	38
November	*	1	6	122	6	123
December	*	21	1	62	1	83
Total	3	50	172	744	175	794
	Annual catch[2]					
Albacore	0	0	0	0	0	0
Yellowfin tuna	0	25	33	249	33	274
Bigeye tuna	0	0	0	1	0	1
Bluefin tuna	0	0	0	*	0	*
Skipjack tuna	9	85	563	2303	572	2388
Total tunas	9	110	596	2553	605	2663
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	0	*	2	13	2	13

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 84.--Estimated catch and effort by Japanese baitboats around Guam and the Northern Mariana Islands, 1977.

	Guam (A)		Northern Marianas (B)		Areas combined (A + B)	
	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ	Within 50 mi.	Within FCZ
	Monthly nominal effort[1]					
January	0	0	*	32	*	32
February	0	0	45	167	45	167
March	16	227	10	36	26	263
April	10	73	20	65	30	138
May	*	6	0	2	*	8
June	0	2	55	172	55	174
July	0	1	52	150	52	151
August	*	5	25	107	25	112
September	1	2	16	99	17	101
October	0	2	8	70	8	72
November	0	13	11	170	11	183
December	0	2	1	39	1	41
Total	27	333	243	1109	270	1442
	Annual catch[2]					
Albacore	0	0	*	5	*	5
Yellowfin tuna	0	13	63	431	63	444
Bigeye tuna	0	1	1	6	1	7
Bluefin tuna	0	1	0	8	0	9
Skipjack tuna	94	2044	846	2995	940	5039
Total tunas	94	2059	910	3445	1004	5504
	Annual catch[2]					
Frigate tuna	0	0	0	0	0	0
Others	0	7	15	70	15	77

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 85.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1971.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	12	0	0	0	0	12
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	12	0	0	0	0	12
			Annual catch[2]			
Albacore	36	0	0	0	0	36
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	409	0	0	0	0	409
Total tunas	445	0	0	0	0	445
			Annual catch[2]			
Frigate tuna	0	0	0	0	0	0
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 86.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1972.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	3	0	0	0	0	3
July	0	0	0	0	0	0
August	6	0	0	0	0	6
September	32	2	0	0	0	34
October	0	0	2	0	18	20
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	41	2	2	0	18	63
			Annual catch[2]			
Albacore	169	0	2	0	147	318
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	0	0	0	0	*	*
Skipjack tuna	1093	57	59	0	567	1776
Total tunas	1262	57	61	0	714	2094
			Annual catch[2]			
Frigate tuna	0	0	3	0	4	7
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 87.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1973.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	1	0	0	0	0	1
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	41	0	0	0	0	41
August	52	0	0	0	0	52
September	7	0	0	0	0	7
October	4	0	0	0	0	4
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	105	0	0	0	0	105
			Annual catch[2]			
Albacore	578	0	0	0	0	578
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	0	0	0	0	0	0
Skipjack tuna	2773	0	0	0	0	2773
Total tunas	3351	0	0	0	0	3351
			Annual catch[2]			
Frigate tuna	0	0	0	0	0	0
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 88.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1974.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	*	0	0	0	0	*
June	1	0	0	0	0	1
July	67	0	0	0	0	67
August	6	0	0	0	0	6
September	1	2	0	0	0	
October	0	0	0	0	0	
November	0	0	10	0	1	11
December	0	0	0	0	0	0
Total	75	2	10	0	1	88
			Annual catch[2]			
Albacore	210	0	80	0	*	290
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	*	0	1	0	0	1
Skipjack tuna	1853	64	282	0	29	2228
Total tunas	2063	64	363	0	29	2519
			Annual catch[2]			
Frigate tuna	0	0	0	0	0	0
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 89.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1975.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	2	2
February	0	0	12	0	2	14
March	19	0	8	0	0	27
April	168	0	0	0	0	168
May	0	0	0	0	0	0
June	23	0	0	0	0	23
July	205	2	0	0	0	207
August	37	2	6	0	0	45
September	15	0	0	0	4	19
October	31	0	0	0	0	31
November	2	0	0	0	0	2
December	1	0	0	0	0	1
Total	501	4	26	0	8	539
			Annual catch[2]			
Albacore	2534	*	172	0	0	2706
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	*	0	3	0	0	3
Skipjack tuna	12321	103	719	0	194	13337
Total tunas	14855	103	894	0	194	16046
			Annual catch[2]			
Frigate tuna	2	0	0	0	0	2
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 90.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1976.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	1	0	0	0	0	1
February	0	0	0	0	0	0
March	1	0	0	0	0	1
April	0	0	0	0	0	0
May	1	0	0	0	0	1
June	1	0	0	0	0	1
July	82	3	0	0	0	85
August	27	2	17	0	0	46
September	5	0	6	1	71	83
October	3	0	0	0	8	11
November	1	0	0	0	0	1
December	0	0	0	0	2	2
Total	122	5	23	1	81	232
			Annual catch[2]			
Albacore	406	2	190	8	808	1414
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	4	0	2	0	3	9
Skipjack tuna	2984	112	563	27	2069	5755
Total tunas	3394	114	755	35	2880	7178
			Annual catch[2]			
Frigate tuna	1	0	*	0	0	1
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

Table 91.--Estimated catch and effort by Japanese baitboats in the FCZ around Wake Island, Johnston Atoll, Palmyra Island and Kingman Reef, Jarvis Island, and Howland and Baker Islands, 1977.

	Wake	Johnston	Palmyra-Kingman	Jarvis	Howland-Baker	Total
			Monthly nominal effort[1]			
January	0	0	0	0	0	0
February	*	0	0	0	4	4
March	0	0	0	0	3	3
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	261	11	1	0	0	273
July	66	113	0	0	0	179
August	70	20	5	0	47	142
September	5	6	109	0	16	136
October	3	5	132	0	8	148
November	20	0	25	0	*	45
December	2	0	5	0	0	7
Total	427	155	277	0	78	937
			Annual catch[2]			
Albacore	2326	1092	2494	0	600	6512
Yellowfin tuna	0	0	0	0	0	0
Bigeye tuna	0	0	0	0	0	0
Bluefin tuna	5	8	34	0	0	47
Skipjack tuna	11570	4376	7330	0	2134	25410
Total tunas	13901	5476	9858	0	2734	31969
			Annual catch[2]			
Frigate tuna	2	6	39	0	0	47
Others	0	0	0	0	0	0

[1]Effort in vessel days, * = < 1 vessel day.
[2]Catch in metric tons, * = < 1 mt.

A MULTISPECIES HOUSEHOLD PRODUCTION ANALYSIS OF RECREATIONAL FISHING WITH DISPOSITIONAL BENEFITS

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A MULTISPECIES HOUSEHOLD PRODUCTION ANALYSIS OF RECREATIONAL FISHING WITH DISPOSITIONAL BENEFITS

The most common management measures for recreational fisheries involve controls on number of fish landed by species, fish size, and number of fishing trips. Previous studies in recreational fishing do not combine all these policy variables to evaluate their interdependency in the recreationalist's consumption decision. Furthermore, previous studies, which attempt to estimate the marginal valuation of fishery resources used in recreation, do not recognize the commercial or subsistence benefits generated when the recreational catch is sold or kept for home consumption. This can lead to misinterpretations of the value estimates placed on the resource and of the estimated behavior in recreational fisheries. In the present study the theory of household production is applied to recreational fishing to include each of the most common policy variables. The results of this application in the conceptual model show that the usual interpretations of recreational resource values are altered when use of the resource also involves commercial or subsistence activities. Except in catch-and-release fisheries, these dispositional benefits are usually present.

The theory of household production applied in the next section represents a new interpretation of consumer choice theory developed by Becker, Lancaster, and Muth. Simply put, households combine goods and time to produce final commodities for consumption. In recreational fishing,

certain attributes are used to describe the activity. This approach contains a more complete framework to impute values directly to the fishery resource and analyze the consumption behavior in the recreational activity. Shortcomings of the travel-cost and direct-interview methods of estimating resource values are discussed by Cocheba and Langford. Hammack and Brown develop a greatly improved method of resource valuation based on an extension of the direct interview approach which has much in common with the household production approach used in the present paper. However, their model does not recognize the interdependency between policy variables since resource demand functions are estimated by imposing a priori restrictions in the empirical model. Also, they do not consider dispositional benefits in their interpretation of the results.

The developed household production model for recreational fishing is tested using a two-step hedonic procedure. Rosen develops the procedure by combining the theory of household production with the practice of adjusting price indexes for quality changes in goods (Griliches). Brown, Charbonneau and Hay use the procedure in a study of fish and wildlife recreational resources. But they do not evaluate the interdependency between species captured. Also, the important policy variable of animal size was not available in their data for analysis, nor did they interpret their results with due considerations for dispositional benefits.

The present study, then, extends the previous work in outdoor recreation by showing the impact of dispositional benefits on the marginal valuation of recreational resources in a conceptual model; estimating the demand for a fishery resource when it is measured in fish size as well as number of fish; and, in demand, estimating interspecies relationships for a

multispecies fishery. Finally, these results are used to assess changes in welfare for policy measures which affect catch rates by species. The results may also be used to assess policies changing the mean fish size of the catch and the annual number of household boating trips.

Conceptual Model

"Pure Sport" Model of Recreational Boating and Fishing

A commodity in household production theory is analyzed as being characterized by a bundle of attributes. The attributes embodied in a boating activity, B, are total number of fish landed, c, mean size of the fish landed, s^c, number of boating trips with participation in a fishery, t^r, and number of boating trips which do not involve fishing, t^g. Expressing the boating commodity as a function of its attributes we have

$$B = B(c, s^c, t^r, t^g) . \tag{1}$$

Each boating commodity is differentiated by the combination of attributes given in equation (1). The combinations of attributes are sufficiently large for the household choice among the alternative boating commodities to be continuous. However, there may exist some constraints that limit the feasible set of attribute combinations. For example, it is not technically feasible in the model to land fish without taking a fishing trip. However, within the feasible set of boating commodities a sufficiently large number of combinations of c and t^r exist for the choice to be continuous. This assumption implies that the catch per trip will vary between households. A further assumption is that the household consumes only one type of boating commodity and commits itself to the

choice at the beginning of the fishing season. Since the boating commodity is differentiated by the attributes, the amount households pay for the commodity is influenced by the attributes.

$$P = P(B) = P(c, s^c, t^r, t^g) . \tag{2}$$

Total expenditures for the boating activity, P, are expressed as a function of the same attributes which characterize the activity.

The household consumption decision is formulated by considering a well behaved utility function,

$$U = U(x, B) \tag{3}$$

where x is all other goods. It is assumed that the marginal rate of substitution between any pair of boating attributes is functionally independent of x. Substituting for B, the utility function then is rewritten as

$$U = U(x, c, s^c, t^r, t^g) . \tag{4}$$

The budget constraint is developed from money-time resources available to the household and money-time expenditures. Income, y, is equal to the product of work time, t^w, and wage rate, w.

$$y = t^w w . \tag{5}$$

Total available time, t, is equal to the sum of work time, other household activity time, t^x, and the two components of boating time.

$$t = t^w + t^x + t^r + t^g . \tag{6}$$

Solving for t^w in equation (6), substituting into equation (5) and rearranging yields the money-time resource or full income.

$$tw = y + t^x w + t^r w + t^g w . \tag{7}$$

Full income, as developed in the context of household production by Becker, represents the money income if all available time were devoted to work. Equation (7) describes one basic resource since household production theory highlights the tradeoffs between time and goods in the production of final commodities. On the expenditure side of the household budget constraint the total money and time costs, E, of all inputs to produce x and B are

$$E = x + P(B) \tag{8}$$

where the price of x is one and only one unit of B is consumed. Equating the household's resources, tw, in equation (7) with expenditures, E, in equation (8) yields the household budget constraint

$$y + t^x w + t^r w + t^g w = x + P(B) . \tag{9}$$

This constraint states that total money and time resources available to the household are expended on the goods and time required to obtain final household commodities.[1]

tnote 1

Assuming a competitive implicit market exists for each boating attribute and each market is in equilibrium, then the implicit price for an attribute is measured by the first derivative of P(B) in equation (2) with respect to the attributes (Rosen). The following interpretations of the implicit prices for the boating attributes are developed from the

first order conditions for maximizing equation (4) subject to equation (9) where λ is the Lagrange multiplier. (Subscripts indicate derivatives.)

$$P_c = \frac{U_c}{U_x} = \frac{1}{\lambda}(U_c) \tag{10}$$

$$P_{s^c} = \frac{U_{s^c}}{U_x} = \frac{1}{\lambda}(U_{s^c}) \tag{11}$$

$$P_{t^r} = \frac{U_{t^r}}{U_x} + w \tag{12}$$

$$P_{t^g} = \frac{U_{t^g}}{U_x} + w \tag{13}$$

In this initial model the household makes no other use of the fish resource except in the game of capture. Therefore in equations (10) and (11) a necessary condition for utility maximization is that the household adjusts c and s^c until its willingness to pay for these qualities of the fishery resource are equated to the rate at which the household is willing to substitute x for c and s^c in recreation alone. In equations (12) and (13) the implicit price of a fishing trip or simple boating trip which does not involve fishing is equal to the sum of the necessary marginal sacrifice of other commodities plus the necessary forgone earnings.

Implicit Prices with Further Use of the Recreational Catch

Fish, like certain types of hunted game, is a unique recreational resource since it may yield benefits as a food source as well as an input to a recreational activity. The recreationally caught fish are at the

household's disposition for either release, home consumption or sale. I refer to the increase in an attribute's implicit price generated by commercial sales or subsistence use of the catch as dispositional benefits. By including the various uses of the fishery resource in the model, the need to select arbitrary definitions for recreational, subsistence, and commercial fisheries becomes unnecessary for analytical purposes. The household considers both recreational and dispositional benefits in its consumption decision. In some fisheries the disposition of catch is used as a management measure. Catch and release fisheries preclude the subsistence or commercial use of the resource. In such fisheries the recreational activity is commonly referred to as a "pure sport"--the absence of non-recreational motivations is one interpretation of the term. In other fisheries commercial sales are prohibited but landing the fish for home consumption is allowed.

Reconsider the household utility function in equation (3) rewritten with, f, the number of fish consumed.

$$U = U(x, f, B) \tag{14}$$

Food fish for home consumption may be purchased at $p(s^f)$ per fish which depends on the size of the market fish, s^f, selected by the household. Fish for home consumption may also be obtained from the household's recreational catch in the course of the boating activity. The recreational catch can alternatively be sold at $p(s^c)$ per fish which will vary by fish size. With this information the budget constraint in equation (9) may be rewritten as

$$y + t^x w + t^r w + t^g w + t^f w + p(s^c)\, c = x + P(B) + p(s^f)\, f \tag{15}$$

The new terms on the left side, $t^f w$ (t^f is the time devoted to fish consumption) and $p(s^c)c$, represent the reallocation of time in full income and the supplement to money income, respectively. Money income is supplemented by $p(s^c)c$ if the catch is sold or if it is kept for home consumption. This assumes no price differential between the ex-vessel and retail levels. Therefore, when s^c equals s^f, as in a subsistence fishery, $p(s^c)$ equals $p(s^f)$. Finally, the new term on the right side of equation (15), $p(s^f)f$, represents the expenditure for food fish.

New implicit prices are derived for the fishery resource from the first-order conditions for maximizing (14) subject to (15) now that disposition of the catch has been introduced into the model. When the catch is commercially sold the equilibrium prices are

$$P_c = \frac{U_c}{U_x} + p(s^c) \tag{16}$$

$$P_{s^c} = \frac{U_{s^c}}{U_x} + \frac{\partial p(s^c)}{\partial s^c} c \,. \tag{17}$$

The price for each measure of the fishery resource is equal to the respective price in the pure sport fishery (equations (10) and (11)) plus marginal revenue. For number of fish marginal revenue is the price per fish . For fish size it is the change in the price per fish with respect to fish size multiplied by the total number of fish landed. The larger the catch the greater are the potential benefits of an increase in fish size. When c is greater than zero, marginal revenue is typically greater than zero since the absolute yield from a fish increases with fish size. However, the price per fish will fall if the commercial price per pound is discounted sufficiently for larger fish.

The implicit prices are expressed differently when the catch is kept for home consumption as in a subsistence fishery. The monetary equivalent of a marginal unit of utility is $1/\lambda$ which may be written as

$$\frac{1}{\lambda} = \frac{1}{U_x} = \frac{p(s^f)}{U_f} \tag{18}$$

from the first order conditions. Under the conditions of a subsistence fishery discussed above and substituting from equation (18), the implicit prices are rewritten as

$$P_c = \frac{1}{\lambda}(U_c + U_f) \tag{19}$$

$$P_{sc} = \frac{1}{\lambda}\left(U_{sc} + U_f \frac{\partial p(s^c)}{\partial s^c} \Big/ p(s^c)\ c\right). \tag{20}$$

These results show that in a subsistence fishery the household is in equilibrium when it is willing to pay the monetary equivalent of the summation of marginal utilities of fish in recreational activities and food consumption. For the fish size attribute the marginal utility of fish in subsistence is weighted by the relative change in fish price with respect to fish size and number of fish landed.[2]

Typically, then, with the possible exceptions noted, the implicit prices for number of fish landed and fish size will be greater when further use of the catch is permitted. In the presence of dispositional benefits, the marginal valuation of the fishery resource should be associated with the commercial or subsistence use of the resource as well as the recreational use. Table 1 summarizes these results of the household production model.

Application of the Implicit Prices

The household production model for recreational boating is operationalized by use of Rosen's hedonic pricing technique. The procedure follows two steps with assumptions consistent with the above model. The first step as described in the previous section requires the estimation of P(B)--regress total money and time expenditures for the annual boating commodity on the boating characteristics, c, s^c, t^r, and t^g. The specification and choice of functional form for P(B) should serve to duplicate the information acquired by households in their decision making process. Next, calculate the implicit price of each boating attribute by taking the first derivative of P(B) evaluated at the attribute level for each household. In the second step, the estimated implicit prices are used to estimate the demand for fishing attributes in the same way direct observations on prices are used.

Empirical Model and Results

A survey was conducted in Kailua-Kona, Hawaii during 1977. Information is used from 144 households out of a random sample of 450 registered vessel owners. Households were deleted for at least one of the following reasons: Respondent could not be reached; respondent does not fish for relevant species; respondent refused interview; respondent is a commercial fisherman and derives 100% of income from fishing; survey questionnaire not complete; or vessel is used for chartering. Most households have a head of household with a full-time job not related to fishing. Ground transportation costs to the recreational site are not an important factor as in many outdoor recreational studies since households reside at the site.

The Hedonic Price Function

Consistent with the conceptual model, the households surveyed are engaged in a household boating activity composed of number of fish caught, fish size, and different types of boating trips. For purposes of analysis it is desirable to disaggregate the catch into different species. A multispecies analysis recognizes that households in this particular fishery possess some discretion as to which species they catch. This is controlled, in part, by area fished and type of fishing tackle used. Fishermen may also determine what size of fish they catch by choice of vessel and other type of equipment. However, such decisions about size will affect the size of all species caught. Therefore the size attribute is for the aggregate catch rather than by species. In the first-step analysis the hedonic price function P(B) is initially specified in the form[3]

(21) $$P = \alpha + \sum_{i=1}^{6} \beta_i B_i + \sum_{j=1}^{5} \sum_{i=1}^{5} \gamma_{ij} B_i B_j + e$$

where

P = total annual expenditures for goods and time inputs to the boating commodity;

α, β_i, and γ_{ij} are parameters to be estimated;

B_1 = BILL = annual number of billfish landed such as blue marlin, black marlin, striped marlin, spearfish, and sailfish;

B_2 = GAME = annual number of other gamefish landed such as mahimahi and wahoo;

B_3 = TUNA = annual number of tuna landed such as skipjack tuna and yellowfin tuna;

B_4 = SIZE = mean size of fish in pounds for total fish landed;

B_5 = FTRIP = annual number of fishing day trips;

B_6 = NFTRIPS = annual number of boating day trips which do not involve fishing; and

e is a random error term.

As Rosen explains, actual specification of equation (21) should serve to capture as much of the systematic information available in the data--information used by households in their household production and consumption decisions. To accomplish this, subsets of the data were investigated to evaluate if different groups of households made use of different types of information in their household decision. The households are stratified into three groups by how many years they have participated in boating with their current vessel. The three groups are identified as new (one full year or less), intermediate and established (four years or more). The model specification differs for each group and follows one method suggested by Theil and used in other hedonic pricing models (Witte, Sumka and Erekson). For each group, those variables in equation (20) with a t-ratio of less than one are dropped with consideration for joint significance. The results in table 2, using ordinary least squares, reflect this choice. The results are interpreted by taking the first derivative of equation (20) for each attribute to calculate implicit prices for each of the 114 households. The mean implicit price for increasing the catch by one fish is $140 for a billfish, $30 for other gamefish, and $18 for an additional tuna. If the average fish landed weighed one additional pound, the household would pay $11 for the marginal increase in total pounds landed. The prices for each species of fish and fish size are reasonable

estimates given the interpretation of the implicit prices developed in the household production model.[4] The implicit price for one additional boating trip is $122 if the trip involves fishing. The estimated price for a non-fishing trip is $51, but it is assumed that an implicit market does not exist for this attribute. Over 95% of the boating trips involve fishing, therefore in the second-step analysis markets are only described for the five fishing attributes. These results show that the value of a fishery can be measured in different ways--the value of the resource in number of fish or fish size and the value fishermen place on a fishing day-trip, holding other attributes constant.

The Demand for Fishing Attributes

In the second-step analysis the estimated implicit prices are used to estimate the demand function for each fishing attribute. The demand function for the i^{th} attribute is

$$P_i = P_i(B_1, \ldots, B_i, \ldots, B_5, \text{NFTRIP}, \text{INC}, \text{AGE}) \tag{22}$$

where the B_i's and NFTRIP are as defined previously, INC is annual household income in $1,000 and AGE is age of the head of household. The demand functions are estimated using ordinary least squares. The parameter estimates are subject to bias due to simultaneous changes in attributes and shifts in supply caused by differences in costs or expertise in fishing across households. Cost differences may be measured by access to better information about fishing conditions through angling clubs, whether the vessel is trailered to a launch site or moored, the number of passengers the vessel is designed to accommodate, familiarity with fishing methods, and the fisherman's familiarity with the fishing grounds. The results of the second-step analysis are summarized in table 3.

Price and quantity are inversely related in demand for four out of five fishing attributes.[5] The marginal implicit price of billfish is not affected by incremental changes in the billfish catch, holding other things constant. The marginal valuation of gamefish decreases about $6 for an increase of one gamefish while the marginal implicit price for tuna decreases only about $1 for an increase of one tuna. If the size of each landed fish increases on the average of 1 pound then the willingness to pay for fish size would decrease about $0.61. The marginal implicit price for a fishing trip will fall about $1 if the household takes one additional trip.

Footnote 5

A point of interest in a multispecies analysis is the interaction between species. If species are determined to be biologically independent, piecemeal steps are usually taken to manage each species. However, the implicit markets for the species may be interrelated as the results here indicate. Four out of the six coefficients are significantly different from zero showing that the species in this fishery can be either substitutes or complements for each other in consumption. Tuna and other gamefish are substitutes since an increase in the number of gamefish causes the implicit price of tuna to fall. The results of the theoretical model indicate that the substitution between these two species can be explained by more than just substitutes in the demand for recreational fishing. The results may also reflect substitution of the species in commercial sales or in food consumption, as in the case of a subsistence fishery. The results also indicate that billfish and gamefish are complements in demand. But this is qualified by the possible correlation of these attributes in supply--even though we assume in the model that a sufficiently

large combination of species is available to the household for the choice to be continuous. A second complementary relationship exists between billfish and tuna. An increase in number of billfish landed increases the demand for tuna. A priori, there are stronger reasons to expect the interspecies relationship to reflect substitution, as between tuna and other gamefish, or independence rather than reflect a complement relationship. However, there are two possible activities which may explain part of the apparently anomolous result of billfish being a complement good for tuna. First, the smaller tuna are sometimes used as live bait for billfish so that part of the demand for tuna may be derived from the demand for billfish. The practice of using the tuna catch for billfish bait does not seem so prevalent, though, that the two products should be identified as joint products in production. But the activity may influence the estimated complementary relationship. Secondly, commercial buyers of the recreational catch deal mostly in tuna. Fishermen who want to sell their billfish catch may find it less costly to find a buyer and more rewarding in price if they can sell tuna to the buyer also. There is no evidence of such tying sales, but scattered instances of this practice may also explain part of the estimated complementary relationship.

Holding catch by species constant the marginal valuation of billfish and gamefish are affected in different ways by a change in the mean fish size. An increase in the mean fish size prompts the household to place a higher marginal value on a billfish. This follows from the trophy value placed on larger billfish in recreation. For example, a 1 pound increase would prompt fishermen to be willing to pay about $4 more for a billfish. But a marginal increase in the mean fish size causes a fall in the demand for

fish size. This could be explained, in part, by the desire of households to land a given quantity of gamefish in pounds. Therefore, if the household is able to land more gamefish (or tuna) in number, then it is not willing to pay as much for a marginal improvement in fish size.

Fish size clearly serves as an important determinant of demand for fishing trips. As the size of the total catch increases, the marginal valuation of a fishing trip increases. And it also holds that the more active the household is in the fishery, as measured by the annual number of fishing trips, the more the household is willing to pay for an increase in fish size.

As one might expect, total catch of gamefish and total catch of tuna are complements with fishing trips. This is evident in the demand functions for gamefish and tuna, and in the demand function for fishing trips. However, fishing trips and billfish catch are substitutes in consumption. This result indicates that households taking fewer trips per year are willing to pay more to catch and land a billfish than households which fish more often.

The remaining independent variables, non-fishing trips, income, and age, are significantly different from zero in four instances. The more non-fishing trips a household takes during the year the less it is willing to pay for a marginal improvement in fish size. An increase in income increases the demand for fishing trips but decreases the demand for tuna. The revenue from tuna sales and the use of tuna for home consumption represent important supplements to money income for the lower income groups in the survey. It is likely that as income increases these households substitute away from tuna to both other types of recreation and other

sources of food. Age is inversely related to the demand for fishing trips. This concludes a description of the consumption behavior in the fishery. The following section demonstrates the different ways these results can be used to assess policy issues.

Consumer's Surplus

Measures of consumer's surplus for a household may be approximated from the estimated demand curves to assess the gains or losses in welfare associated with alternative public policies. Suppose, for example, a policy increases the catch rate for a particular species, reduces costs and results in a 10% increase in the economic equilibrium total catch for that species. The resulting incremental increase in consumer's surplus in the implicit market for that species represents the gain to households if supplies are sufficiently elastic in the other attribute markets for other prices not to be affected. The gain associated with billfish, other
tnote 6 gamefish and tuna, individually, is $11, $82, and $72, respectively.[6] Other policy measures which influence the mean fish size or annual number of fishing trips can be evaluated in the same manner. If supplies are less elastic in the other markets, then the full assessment of the gain (or loss) would depend on the supply curves in those markets as well as the demand curves.

Summary and Conclusion

The theory of household production serves as a framework to evaluate implicit markets and assess welfare implications of policy measures in outdoor recreation. In recreational fisheries each of the most common

policy variables are incorporated into a household production model of a boating activity. The activity is characterized by number of fish landed by species, fish size, number of fishing trips, and number of non-fishing trips. From the results of the conceptual model it is concluded that the marginal valuation of the fishery resource depends on how the resource is measured (number of fish landed and fish size) as well as the disposition of the catch (release, commercial sales or subsistence). These findings extend previous recreational fishing studies which assume fish size does not generate recreational benefits independent of the quantity of fish landed. Furthermore, the findings extend previous studies in outdoor recreation relevant to resource valuation which do not explicitly recognize the impact of dispositional benefits in the consumption decision. Fishermen consider all associated benefits derived from the fishery resource. The interpretations of the estimated marginal values for the boating attributes and interaction between policy variables in household consumption behavior should reflect the commercial and subsistence use of the recreational resource.

The implicit prices estimated for billfish, other gamefish, and tuna in a Hawaii fishery represent the marginal value placed on these species in recreation, commercial sales, and subsistence fishing combined. The implicit price estimated for fish size also represents the dispositional use of the catch as well as recreational use. Using these prices with the estimated price for fishing trips to analyze the implicit demand for each attribute, the interactions between policy variables are described. The interspecies behavior is described by the substitute or complement

relationship between species in demand. Again, the empirical results are interpreted with the findings of the conceptual model. The interaction between species is explained by how they are combined in recreational demand as well as how they are combined in commercial sales and food consumption by the household. The substitution or complementary relationship between catch by species and fish size is explained by the same type of factors. Fish size also interacts with number of fishing trips. The larger the fish size the greater the demand for fishing trips; and conversely, the more a household participates in a fishery the more it is willing to pay for a marginal improvement in fish size. Finally, from the results it is concluded that for certain species the household substitutes between annual catch and annual number of trips. In the case of billfish, households which take fewer trips are willing to pay more for a billfish catch. But households which take more trips are only willing to pay more for other gamefish and tuna catches, reflecting the complementary relationship between these policy variables. The estimated demand curves for each policy variable may be used to assess the welfare implications for different policy schemes. Application of the results for this purpose is demonstrated for policies which increase the catch rates and thus reduce the cost of landing a fish.

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Footnotes

[1]The full income concept used in household production theory appears to be at odds with studies which conclude that the use of the wage rate for the cost of time is inappropriate. These studies analyze the value of travel time in the estimation of recreation benefits (see Cesario for such an analysis and a discussion of other studies). The conflict does not occur in the present study. Travel time is minimal for the participants of the particular fishery analyzed in the empirical section of this paper since they live at the recreation site. Also, it is observed that participants take off work time occasionally to engage in the fishing activity.

[2]Many occupations are recognized for providing non-pecuniary income to workers. If this is the case for a commercial fisherman then the above results show that the marginal valuation of the number of fish landed is understated by the commercial market price. The difference between the full marginal valuation and pecuniary income is the monetary equivalent of the marginal utility of landing a commercial fish or non-pecuniary income. From equations (16) and (18),

$$P_c - p(s^c) = \frac{1}{\lambda}(U_c) .$$

[3]This functional form does not impose a priori constraints on the second derivatives of the equation. Witte, Sumka, and Erekson show that semilog and log linear functional forms used in the first-step analysis of estimating the hedonic price function (common forms used in hedonic price studies) introduce severe bias into the second-step analysis of estimating

Footnotes (continued)

demand functions. A negative relationship is imposed between the estimated implicit price derived from the first-step and the respective attribute quantity regardless of the existence of an implicit market and regardless of the underlying economic behavior.

[4]As discussed in the conceptual model, these marginal value estimates are generated by recreational and dispositional benefits. However, resource values may also be composed of non-consumptive benefits (Cocheba and Langford) and existence benefits (Miller and Menz). Whether these additional benefits are embodied in the above marginal value estimates depends on how these additional uses of the resource are separable from the boating commodity in the utility function.

[5]Coefficients are significantly different from zero at the 0.10 level, two-tail test.

[6]If the demand curves are estimated under the restrictions of symmetrical cross-price terms, then the approximations of the gain are $15, $91, and $103, respectively.

Table 1. Summary of Implicit Prices with Alternative Uses for the Fishery Resource

Boating Attribute		Implicit Price		
		"Pure Sport" Case	With Additional Use of the Fishery Resource	
			Commercial	Subsistence
Number of fish caught (c)	P_c:	$\frac{U_c}{U_x} = \frac{1}{\lambda}(U_c)$	$\frac{U_c}{U_x} + p(s^c)$	$\frac{1}{\lambda}(U_c + U_f)$
Mean fish size (s^c)	P_{s^c}:	$\frac{U_{s^c}}{U_x} = \frac{1}{\lambda}(U_{s^c})$	$\frac{U_{s^c}}{U_x} + \frac{\partial p(s^c)}{\partial s^c} c$	$\frac{1}{\lambda}\left(U_{s^c} + U_f\left(\frac{\partial p(s^c)}{\partial s^c} \Big/ p(s^c)\right) c\right)$
Fishing trip (t^r)	P_{t^r}:	$\frac{U_{t^r}}{U_x} + w$		
Non-fishing trip (t^g)	P_{t^g}:	$\frac{U_{t^g}}{U_x} + w$		

Table 2. Summary Results of First-Step Analysis--Estimating P(B)

Group	Independent Variables								
	Constant	B_1[a]	B_2[b]	B_3[c]	B_4[d]	B_5[e]	B_6[f]	B_1^2	B_2^2
New	-2,060.23	-898.36	411.50		38.78	199.26	234.18		-20.14
	(1,053.00)[g]	(447.81)	(129.06)		(22.35)	(48.31)	(86.51)		(6.16)
Intermediate	3,156.42						-169.12	-52.44	-0.36
	(1,064.70)						(105.54)	(52.84)	(0.64)
Established	1,605.65	(1,067.24)		-4.44			92.42	-61.29	
	(762.69)	(1,098.71)		(40.13)			(85.39)	(216.35)	

Group	B_3^2	B_4^2	B_5^2	B_1B_2	B_1B_3	B_1B_4	B_1B_5	B_2B_3	B_2B_4
New	-0.94	-0.42	-1.98	65.88		15.68	-33.32		-5.77
	(0.47)	(0.18)	(0.47)	(13.01)		(3.43)	(8.76)		(1.58)
Intermediate		-0.45	-0.30	50.17					
		(0.26)	(0.75)	(33.64)					
Established	-0.33				-4.28	-5.42		-0.32	
	(0.26)				(8.79)	(17.45)		(0.40)	

Group	B_2B_5	B_3B_4	B_3B_5	B_4B_5	n	R^2	F
New	5.22		2.89	1.15	39	0.93	19.37
	(2.49)		(0.83)	(0.59)			
Intermediate		-1.32	0.57	2.94	39	0.82	12.55
		(0.59)	(0.42)	(0.89)			
Established			1.79	0.88	36	0.72	6.59
			(0.89)	(0.48)			

[a]Number of billfish landed. [b]Number of other gamefish landed. [c]Number of tuna landed. [d]Mean fish size of total catch in pounds. [e]Number of fishing day trips. [f]Number of non-fishing day trips. [g]Standard error in parentheses.

Table 3. Summary Results for Second-Step Analysis--Estimating the Demand Functions for Fishing Attributes[a]

Implicit Price	Independent Variables									R^2	F
	Constant	BILL	GAME	TUNA	SIZE	FTRIP	NFTRIP	INC	AGE		
P_{BILL}	-57.65	-35.89	16.85***	1.53	4.35*	-11.34***	10.70	-59.53	6.12	0.17	2.69
	(344.32)[b]	(29.08)	(5.97)	(2.29)	(2.43)	(3.32)	(17.03)	(106.82)	(5.88)		
P_{GAME}	12.14	41.46***	-6.50***	-0.61	-2.32***	1.55*	-3.97	23.14	1.31	0.37	7.85
	(80.95)	(6.84)	(1.40)	(0.54)	(0.57)	(0.78)	(4.00)	(25.11)	(1.38)		
P_{TUNA}	30.23	3.10*	-0.70*	-0.68***	-0.21	1.78***	-0.65	-21.48***	-0.12	0.53	14.71
	(21.17)	(1.79)	(0.37)	(0.14)	(0.15)	(0.20)	(1.05)	(6.57)	(0.36)		
P_{SIZE}	-13.57	9.41***	-0.76**	-0.72***	-0.61***	1.50***	-1.67*	3.29	0.35	0.59	18.66
	(17.70)	(1.50)	(0.31)	(0.12)	(0.12)	(0.17)	(0.88)	(5.49)	(0.30)		
P_{FTRIP}	83.21**	-28.36***	2.01***	1.27***	1.67***	-1.03***	0.74	30.31**	-1.28*	0.50	13.15
	(37.78)	(3.19)	(0.65)	(0.25)	(0.27)	(0.37)	(1.87)	(11.72)	(0.65)		

[a] 114 observations.

[b] Standard error in parentheses.

*Coefficient is significant at 0.10 level, two-tail test.

**Coefficient is significant at 0.05 level, two-tail test.

***Coefficient is significant at 0.01 level, two-tail test.

THE COSTS OF PRIMARY JOURNALS: A REVIEW

By

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1. INTRODUCTION

The 18th Session of the Indo-Pacific Fishery Commission (IPFC) reviewed a recommendation by the IPFC Executive Committee that IPFC should start publication of a journal for papers produced by scientists of member countries. During the discussion on the recommendation, views were expressed that (1) not enough thought had been given to the recommendation, (2) the costs mentioned to publish such a journal were much too small for a high-quality publication, (3) publishing a journal was a tremendous undertaking that could not be engaged in lightly, and (4) more information was needed on the subject.

A primary journal has been defined as one in which the results of new research are published (Committee on Scientific and Technical Communication, 1970). The publication recommended by the Executive Committee is assumed to be a primary journal.

The purpose of this paper is to review the costs of publishing a primary journal and thereby answer some of the questions raised on publications at the 18th Session. This review was based entirely on the literature and no attempt was made to obtain data directly from any journal publishers. In analyzing the operations of scientific journals, some researchers make a distinction among society, university, and commercial

publishers (Leeson, 1978). The publication proposed by the Executive Committee would presumably be more similar to those published by society and university than to commercial publishers. No papers on publications costs in countries other than the United States of America were consulted; thus the results of the view only reflect conditions in the U.S.A.

2. THE ROLE OF PRIMARY JOURNALS

Herwald (1967) stated that the basic function of a professional society is the interchange of information, which is done in two basic ways--at meetings and through publications. Journals or publications also have other characteristics or roles. Briefly, they have a current awareness role, that is, in keeping researchers in a field aware of advances made by others, and an archival role. In an archival role they provide the full text of new knowledge that is complete enough to satisfy most users, the material is under orderly bibliographic control and is quickly available in any well-maintained collection. However, because of the many problems of primary journals researchers have wondered whether such journals are anachronisms and should be replaced by other modes of storage and communication of information. This view was rejected on the basis that the growth in the number of journals showed that users (subscribers) are still interested in them and that while new modes of communication offered exciting possibilities they still had to be used in conjunction with journals (Committee on Scientific and Technical Communication, 1970).

3. GENERAL PROBLEMS IN JOURNAL ECONOMICS

Although the importance of the problems of journal economics has long been recognized, it has been noted that as relatively recently as 1969 there

were limitations in the understanding of the economics of journal publications and that few technical societies publishing journals knew their detailed publication costs (Herwald, 1967; Committee on Scientific and Technical Communication, 1969). While there is contradictory evidence on the proliferation of journals (Leeson, 1978), many investigators comment on the "technical information explosion" and the financial problems associated with it, particularly with regard to society publications (Herwald, 1967). A cursory survey of the fishery literature indicated that the IPFC countries have contributed to the proliferation of scientific and technical journals (Table 1). It should be noted that Table 1 only includes fishery publications. Stewart (1963) was struck by the large number of journals in biology as compared with that in the physical sciences and noted that each biology journal served fewer scientists as shown by circulation figures.

Publishers of primary journals have been concerned about meeting their responsibilities in the face of the "information explosion" and the constantly changing needs of scientists, a concern which has been reflected primarily in meeting the cost of publishing (Kuney, 1963). Numerous ways to reduce or balance the cost of publishing have been suggested including ways to reduce cost in the printing and editorial sectors, increasing society dues, increasing the advertising carried, adding page charges, reducing the number of pages published, and changing the physical quality of the journal, e.g. changing from glossy paper stock to a less-expensive stock (Lee, 1954; Herwald, 1967). Koch (1969) suggests that the "federation concept" and the "page charge concept" are the most important operational concepts basic to the favorable operation of the American Institute of Physics (AIP). The

AIP performs communal operations that provide benefits resulting from centralized operations for the member societies in the federation. Page charges were established by AIP to be an equitable contribution by the authors' institutions to cover most of the editorial and composition costs of the pages published for authors.

4. PRODUCTION COSTS OF JOURNALS

The costs of producing a journal can be broken down basically as prerun costs and runoff costs. Included in the prerun costs are costs associated with editorial work, copy editing, composition, proofreading, and engraving. Runoff costs include costs associated with paper and presswork, binding, wrapping, mailing, and monitoring files of subscribers. There may also be optional costs, i.e. costs of operations that are not directly related to the publication of research results but are considered desirable adjuncts, such as preparation and printing of advertising and news material or production of reprints and back-number stocks (Committee on Scientific and Technical Communication, 1970). The prerun and runoff costs of nine AIP journals for the period 1964-69 are shown in Table 2.

Stewart (1963) cited cost figures for the production of 124 biological journals in 1959. Assuming a cost of $20 per page, she estimated that the 106,700 pages published in 1959 cost $2,192,000 or $17,700 per journal. She also noted that using the cost figure of $70 per page estimated by the Federation of American Societies for Experimental Biology an estimate of $7,500,000 or $60,500 per journal would be obtained.

4.1 Prerun Costs

4.1.1 Editorial work

Under editorial work can be listed technical editing which includes editors, clerical staff, referees, telephone, postage, etc. Some items under editorial work are often referred to as "hidden costs" of journal production. Technical editing and refereeing are a significant item in the prerun costs of producing a journal and although editors are often paid, they frequently are not. Even when editors are paid, their remuneration may not be commensurate with the value of the time they devote to their journals.

4.1.1.1 Technical editing

Usually, editors are on the staff of a university or other institutions who devote part time to the journal. A 1968 survey showed that in a subset of 36 journals having part-time editors, 24 were paid a stipend and 12 were not (Committee on Scientific and Technical Communication, 1970). This same study showed that the average compensation for editors who received stipends was around $3,000 per million published words. Stewart (1963) found that 34% of the editors of biological journals were paid (amount not specified). These editors spent an average of 779 hours per year on their journals.

4.1.1.2 Refereeing

Although some journals of private publishers provide an honorarium, referees usually donate their services. The Committee on Scientific and Technical Communication (1970) estimated that the amount of refereeing time per paper refereed was of the same order as the amount of editorial time per paper published.

Koch (1969) noted that for the AIP operations the most significant policy procedure relating to journal quality was the referee system. He found that refereeing, on the average, consumed about half the average total time of 6 months required from the time a manuscript is submitted to the scientific editor to the time it is published.

4.1.1.3 Copy editing

Copy editing is the preparation of manuscripts for the typesetter or other compositor and includes the marking of manuscripts for the typesetter, standardizing headings, footnote arrangement, planning the layout of figures and tables, and some proofreading. Usually most or all of these functions are done at the journal production office, but sometimes they may be done at the technical editor's office and others may be done sometimes by the printer. The 1967 cost (including overhead) of the "editorial mechanics" for a number of scientific and engineering journals and university presses was found to range from about $7.50 to over $28 per 1,000 equivalent words. The cost for most organizations was in the range of $12 to $16 (Committee on Scientific and Technical Communication, 1970).

4.1.1.4 Composition

Composition costs depend basically on whether the journal is set in type or photo-offset from copy prepared on special typewriters in the offices of the journal. Costs of composition are also influenced by the difficulty of the material being set and may differ from printer to printer. In comparing the costs of composition itself, i.e., corrections made to proof and engravings, the costs in 1968 using domestic typesetters were usually in the range of $30 to $40 per thousand equivalent words, depending

noticeably on the amount of mathematics and special symbols involved. Typewriter and photo-offset composition seemed to cost only two-thirds of that for domestic typesetting (Committee on Scientific and Technical Communication, 1970). The Committee also noted that some European typesetters seemed to charge as little as two-thirds the domestic rate and those in the Far East even less.

4.2 Runoff Costs

Basic runoff costs include expenses for paper and presswork, binding, wrapping, mailing, monitoring files of subscribers, and other related items (see e.g. Table 2). The Committee on Scientific and Technical Communication (1970) compared the size of an average issue of the journal with specific runoff costs including (a) printing, paper, and postage, (b) covers, wrapping, and mailing, and (c) maintenance of records and other information on subscribers. The runoff costs in cents per thousand equivalent words per subscriber generally decreased with an increase in thousands of equivalent words per issue.

5. SUMMARY

The motivation for this paper surfaced at the 18th Session of the IPFC during discussions on a recommendation by the Executive Committee that IPFC sponsor a publication. The purpose of this paper is to briefly review some of the costs associated with publishing a primary journal.

The role of primary journals and general problems in journal economics were briefly discussed. Basic production costs of journals have been basically categorized as prerun costs and runoff costs. Prerun operations include editorial work, copy editing, composition, proofreading, engraving,

and related functions. Runoff operations include functions related to presswork and cost of paper, binding, wrapping, mailing, monitoring files of subscribers, etc. Production cost items were discussed in varying degrees of detail and some examples of total cost figures for primary journals were presented.

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TABLE 1. Fishery publications of Indo-Pacific Fishery Commission countries and international/private foundations or organizations associated with IPFC countries

Country	Types	
	Technical	Semitechnical
	IPFC Countries	
AUSTRALIA		
Fisheries Division, Department of Primary Industry		Australian Fisheries (monthly)
Commonwealth Scientific and Industrial Research Organization (CSIRO)	Australian Journal of Marine and Freshwater Research (bimonthly)	
CSIRO Division of Fish and Oceanography	Circular (irregular), e.g. Workshop on lobster and rock lobster. Circ. 7, 1977	
Do	Fisheries synopsis (irregular), e.g. Synopsis of biological data on banana prawn.... Fish. Synop. (8), 1970	
Do	Report (irregular), e.g. Hydrological features of a warm core eddy and their biologcal implications. Rep. 100, 1978	
DO	Research Report 1974-77. [Annual report.]	
CSIRO Marine Biochemistry Unit	Annual Report	
BANGLADESH		
BURMA (Socialist Republic of the Union of)		

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
FRANCE		
Office de la Recherche Scientific et Technique Outre-Mer (ORSTOM)	CAHIERS. ORSTOM Oceanographie (quarterly)	
Institut Scientifique et Technique des Peches Maritimes	Revue des Travaux de l'Institut des Peches Maritimes (quarterly)	
INDIA		
Ministry of Food and Agriculture	Indian Journal of Fisheries (semi-annual)	
Indian Council of Agricultural Research, Central Marine Fisheries Research Institute (CMFRI)	CMFRI Bulletin (irregular)	Marine Fisheries Information Service (CMFRI)
	CMFRI Special Publication (irregular)	
	CMFRI Annual Report	CMFRI Newsletter
INDONESIA		
Lembaga Oseanologi Nasional. Lembaga ilmu Pengetahuan Indonesia	Marine Research in Indonesia (irregular)	
	Oceanographical cruise report (irregular)	

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
JAPAN		
Ministry of Agriculture and Forestry	Fisheries Statistics of Japan (in English) (annual)	
	Statistical Data (in Japanese) (annual)	
Fishery Agency. Research and Development Department	Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fishery (annual)	
	Annual Report of Effort and Catch Statistics by Area on Japanese Skipjack Baitboat Fishery (annual)	
Oceanic Fishery Department	Fishing Boat Laboratory. Technical Report of Fishing Boat (irregular)	
Far Seas Fisheries Research Laboratory	Bulletin of the Far Seas Fisheries Research Laboratory (irregular)	
	S Series (irregular)	
KOREA		
Fisheries Research and Development Agency	Annual Report of Oceanographic Observations (annual)	
	Bulletin (annual)	
MALAYSIA		

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
NEW ZEALAND		
Ministry of Agriculture and Fisheries. Information Services		Catch '80 (monthly)
Fisheries Management Division	Fisheries Technical Report (irregular)	
Fisheries Research Division	Fisheries Research Bulletin (irregular)	
	Occasional Publication (irregular)	
Department of Science and Industrial Research. New Zealand Oceanographic Institute (NZOI)	Contribution (irregular)	
	Memoir (irregular)	
	Miscellaneous Publication (irregular)	
	NZOI Records (irregular)	
	Coastal Series Charts (irregular)	
PHILIPPINES		
Bureau of Fisheries and Aquatic Resources	Fisheries Statistics of the Philippines (annual)	Fisheries Newsletter (quarterly)
	Philippine Journal of Fisheries (semiannual)	Fisheries Today (quarterly)
SRI LANKA	Bulletin of the Fisheries Research Station, Sri Lanka (Ceylon) (semiannual)	
THAILAND		
Ministry of Agriculture and Cooperatives. Department of Fisheries	Phuket Marine Biological Center. Research Bulletin (irregular)	

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
UNITED KINGDOM		
Ministry of Agriculture, Fisheries and Food	Fishery Investigations, Series II (irregular)	
	Fisheries Research Technical Report (irregular)	
	Laboratory Leaflet (irregular)	
	Report of the Director of Marine Fisheries Research	
Institute of Oceanographic Sciences	Collected Reprints (annual)	
	Annual Report	
UNITED STATES OF AMERICA		
National Marine Fisheries Service	Fishery Bulletin, U.S. (quarterly)	Marine Fisheries Review (monthly)
	Report of the National Marine Fisheries Service (annual)	
	Statistical Digest (annual)	
	NOAA Technical Report NMFS Circular (irregular)	
	NOAA Technical Report NMFS SSRF (irregular)	
VIETNAM (Socialist Republic of)		

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
International/Private Foundation or Organizations		
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS		
Indian Ocean Fishery Commission (IOFC)	IOFC/DEV/Programme Publications (irregular)	
	IOP/TECH (Technical Reports) (irregular)	
IPFC	Proceedings (biannual)	IPFC Newsletter (irregular)
	Occasional Papers (irregular)	
	Regional Studies (irregular)	
	Special Publications (irregular)	
United Nations Development Programme (UNDP) South China Sea Fisheries Development and Coordinating Programme	Fisheries Technical Papers (irregular) SCS/DEV/__	
	Manuals - SCS Manuals (irregular)	
	Working Papers - SCS/yr/WP__ (irregular)	
	Coordinating Committee Reports (irregular) - SCSP: yr/no/REP__	
	Workshop Reports - SCS/GEN/__ (irregular)	
	Periodic Progress Reports - SCS/PR/__	

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT (ICLARM)	Studies and Reviews (irregular)	ICLARM Newsletter (quarterly)
	Conference Proceedings (irregular)	
INTER-AMERICAN TROPICAL TUNA COMMISSION (IATTC)	Annual Report	
	Bimonthly Progress Report	
	Bulletin (irregular)	
	Data Report (irregular)	
	Internal Report (irregular)	
	Special Report (irregular)	
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER (SEAFDEC)		
Aquaculture Department	Annual Report	
	Quarterly Research Report	
	Technical Report (irregular)	
	Extension Manual (irregular)	
Marine Fisheries Research Department	Report (annual)	
Secretariat		SEAFDEC Newsletter (irregular)

TABLE 1. (Continued)

Country	Types	
	Technical	Semitechnical
SOUTH PACIFIC COMMISSION (SPC)	Annual Report	SPC Fisheries Newsletter (irregular)
	Bulletin (quarterly)	SPC Monthly news of activities (monthly)
	Occasional Paper (irregular)	
	Report (annual)	
	Skipjack Survey and Assessment Programme (annual; interim)	
	Statistical Bulletin (irregular)	
	Technical Paper (irregular)	

TABLE 2. Consolidated prerun and runoff costs for nine American Institute of Physics journal (adapted from Koch, 1969)

	1964	1965	1966	1967	1968	1969
Prerun Costs						
Income						
Page charge	$680,661	$783,026	$ 858,609	$1,044,794	$1,057,283	$1,164,050
Conference contribution	6,500	12,000	9,000	17,800	32,097	10,000
Expense						
Composition and authors' alterations	$479,012	$582,518	$ 657,609	$ 704,492	$ 733,991	$ 788,100
Engravings	63,273	71,188	86,350	95,936	101,352	104,200
Editorial management	136,836	124,477	137,131	146,453	165,913	172,450
Editorial mechanics	106,358	122,104	141,126	173,444	212,267	233,600
Cost of free reprints[1]	40,069	45,236	50,427	55,045	56,979	65,150
Order handling charge[1]	8,576	15,588	18,104	18,308	22,478	27,650
	$834,124	$961,111	$1,090,747	$1,193,678	$1,292,980	$1,391,150
Statistical Data						
Number of text pages (including blanks and covers)	18,129	20,613	22,636	24,799	26,153	26,232
Text pages less 2%	17,766	20,201	22,183	24,283	25,630	25,707
Input cost/corrected page	$46.95	$47.58	$49.17	$49.16	$50.45	$54.12
Runoff Costs						
Income						
Subscriptions	$608,445	$639,711	$654,267	$785,826	$788,057	$792,750

TABLE 2. (Continued)

	1964	1965	1966	1967	1968	1969
Expense						
Printing	$329,467	$371,609	$411,294	$458,820	$410,737	$433,700
Mailing					93,019	99,300
Subscription handling	83,524	71,624	66,392	68,512	71,433	74,650
Circulation promotion	5,452	6,895	3,884	230	--	--
Total	$418,443	$450,128	$481,570	$527,562	$575,189	$607,650
Statistical Data						
Number of text pages (including blanks and covers)	18,129	20,613	22,636	24,779	26,153	26,232
Text pages less 2%	17,766	20,201	22,183	24,283	25,630	25,707
Output cost/corrected page	$23.55	$22.28	$21.71	$21.73	$22.44	$23.64

[1]Estimated.